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AN EXPERIMENTAL STUDY OF THE LOAD-
CARRYING CAPACITY OF STEEL ROLLERS

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B.S., University of Illinois, 1927

THESIS

Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science in Civil Engineering
in the Graduate School of the
University of Illinois, 1929

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I. INTRODUCTION.

I. INTRODUCTION.

1. Foreword. Some means should be provided to permit the end of a stiff structure to move, thereby relieving the excessive thrust which would otherwise develop when the structure expanded due to a change in temperature or stress. In the practice of bridge engineering, one end of the structure is placed on a nest of rollers which allows free longitudinal expansion of the bridge. This use of rollers is illustrated by the diagram of Figure 1.

In the rolling bascule bridge, the leaf extending across the channel is continued shoreward in the form of a circular segment. The structure is counterweighted so the center of gravity of the entire mass is at the center of the segment. As the bridge opens, it rolls shoreward on the cylindrical surface which bears on a plate girder paved with steel sole plates. The construction and action of a rolling lift bridge are shown in Figure 2.

Small rollers as used in expansion nests seem to function very well under the stresses for which they are designed, but there is a possibility of present practice being too conservative. There have been some costly failures of the sole plates of bascule bridges. Notable among these are the Causeway Bridge at Galveston, Texas and the Cherry Street Bridge in Toledo, Ohio.

There are very few experimental data available giving the bearing value of rollers. A mathematical solution of the problem would be very complicated and would require experimental verification as well as the determination of certain empirical constants. For these reasons this experimental investigation has been undertaken.



Fig. 1
Roller Nest Under a Fixed Span

2. Objects. The objects of this investigation were:

- a. To develop a method of testing small rollers.
- b. To obtain data upon which to base the design of small rollers.
- c. To correlate the work that had been done on large and small rollers.

3. Scope. The tests for the bearing value were made on rollers varying in diameter from 2 inches to 116 inches. The only variable studied was the diameter of roller. The cylinders less than 24 in. in diameter and all the bearing plates were cut from a single medium grade steel casting and received the same heat treatment. The segments for the cylinders larger than 24 in. in diameter were cut from a casting from the same heat as the other and received similar heat treatment. The plates were all $1\frac{1}{2}$ inches thick and 4 inches wide. The effect of rolling on the hardness of the material as indicated by the Brinell hardness test was studied. The strength of the material was determined by tension tests.

A separate study was made on the effect of the depth of the plate upon the bearing value. The block was an annealed steel casting of medium grade. The depth of plate varied from $8\frac{1}{2}$ inches to $1\text{-}\frac{3}{8}$ inch. The roller was 116 inches in diameter.

A study was made of the elastic flow of a plate in an attempt to develop a means of determining the critical load from the elastic flow. The flow was measured in the direction of and normal to the plane of rolling.

An analytical study was made to determine the carrying capacity of steel castings having an H-section.

Rolling tests were made on steel castings having a V-shaped top flange, with and without stiffeners, also on castings having rectangular sections. Each shape was made of two materials, carbon steel casting and a high manganese steel casting^{sold} under the trade name of Mylastic Steel. The diameter of the roller was 236 inches.

4. Acknowledgments. The experimental work of this thesis was performed as a part of one of the projects of the Engineering Experiment Station of the University of Illinois of which Dean W.B. Ketchum is the Director and in the Department of Civil Engineering of which Professor W.C. Huntington is the Head.

The writer is very grateful to Professor W.W. Wilson, under whose supervision the testing was done, for his encouragement and many helpful suggestions. The work of Mr. W.T. Pope, machinist for the Structural Laboratory, in machining and finishing the specimens is appreciated, also his useful suggestions. The writer is indebted to Mr. Ralph Kluge, Graduate Research Assistant in the Engineering Experiment Station, for a great amount of help in performing the tests. The heat treatment of the specimens was done under the supervision of Mr. E.T. Lanham, Superintendent of the Forge Laboratory, to whom the writer is grateful. Mr. James Hardeety and Dr. H.W. Westergaard gave valuable assistance with Part II.

5. Definitions and Explanations. The range of the diameter of rollers covered by this thesis is quite wide. The term large roller shall be applied to those whose diameter is greater than 24 inches. The term small roller shall be applied to those whose diameter is less than 24 inches. This distinction is made because

the method of testing of the two groups is different, and not because of any difference in their action.

A flow of metal accompanies the rolling of a plate under a loaded cylinder if the load is great enough to produce a stress greater than the elastic limit of the material. The metal flows in all directions in the horizontal plane. The flow in the direction of the plane of rolling is termed the longitudinal flow. This is also the direction of the long side of the plate.

The flow normal to the plane of rolling or in the direction of the axis of the roller is termed lateral flow. This is also the direction of the short side of the plate.

The flow of metal in the roller was measured in only one direction. That was in the direction of the axis of the roller and adjacent to the line where lateral flow was measured in the plate. The flow of metal in the roller is called the spread of roller. It may also be defined as the change in length of the roller.

Curves showing the relation between load and deformation are given for each test. In some cases the relation is very nearly constant, then suddenly increases. In other cases the relation between flow and load is given by a curve with no definite break. The load at which the break in the curve occurs or at which the flow becomes excessive is termed the critical load or the load producing failure. The method of determining the critical load from the curves is explained in Section VII paragraph 1.

PART I.

ROLLING TESTS OF SMALL ROLLERS.

11. RESUME OF FORMER TESTS.

PART I. ROLLING TESTS.

II. RESUME OF FORMER TESTS.

1. Introduction. The material in this section has been taken largely from the thesis of Mr. W.K. Brown and Mr. K.C. Hartmann, An Experimental Study of Cylinders Bearing on Plane Surfaces, 1927.

The work of mathematical analysts leads to formulae which are complicated and a discussion of which is beyond the scope of this thesis.

Of the experimental work on rollers, only those tests of interest in this thesis will be presented.

2. Experiments by Wing and Crandall. In 1887, "Professor Crandall, assisted by Mr. Wing, conducted a series of tests to determine the wearing qualities and life of rollers for various loads and materials. The apparatus for testing consisted of 3 horizontal plates separated by 3 parallel rollers, one above and two below the middle plate. The load was distributed equally between the two lower rollers. The middle plate was moved back and forth about $3/4$ of an inch by a mechanical attachment. The results of the tests showed that wearing of the surface was accompanied by a gradual rusting and blackening of the material, a black dust forming as the wearing increased. Flow of metal occurred at the sides of the rollers and around the edge of contact area on the base, at a load of 3260 pounds per inch of length on a steel roller 2 inches in diameter.

3. Experiments by Marston. "Anston Marston first began his study of small rollers at Cornell University in 1887. His first work consisted in using polarized light to study the stress distribution in optical glass rollers and plates. Tests were made at several loads, his results checking closely the intensities of the principal stresses as given by formulae based on the equations of elasticity.

"Later, in 1893, Marston continued his investigation at Iowa State College to determine the elastic limit load for rollers bearing on plane surfaces. Rollers having diameters of 1, 2, 3, 4, 6, 10, 12, 14 and 16 inches and 1 inch wide were tested upon bases 6 inches square and 0.9 inches thick. All rollers and bases were cut from the same plate of mild steel, bearing surfaces being highly polished by hand. The procedure of these tests was to apply static loads by increments, examining the surfaces carefully following each load to detect any set that might have occurred. Set was detected by holding the plate and roller to a light in a favorable position. No means of measuring this indentation was employed. Marston found that the smallest load producing a detectable set, thus determined, varied directly as the diameter and was equal to $880D$, where the load is in pounds per linear inch of cylinder and D is the diameter in inches.

4. Experiments by Deslandres. "M.H. Deslandres tested three rollers bearing on cast iron plates 3.15 inches thick. A cast steel roller 9.45 inches in diameter and two cast iron rollers 6.30 inches and 4.72 inches in diameter were tested, the width of

rollers and plates in all cases being 7.87 inches. Measurements were made to determine the permanent set in the surface of the cylinders and plates following the application of successive static loads. The surface of the roller and plate was divided into seven equidistant sections. The compressed diameter at the various sections was compared with the diameter making an angle of 45 degrees with that diameter. A caliper scale was used that could be read with a maximum error of .002 m.m. (0.00008 inches.) Corresponding observations were made with the same degree of accuracy upon the bases with the use of a plane tester. Deslandres' experiments showed that the permanent set was proportional to the load up to some critical load, beyond which the set increased rapidly with an increase in load. There seemed to be no easily expressed relation between the critical load and the diameter of the roller for the three tests presented.

5. Experiments by Wilson. "Professor Wilson has determined the bearing value of large rollers under two conditions of loading, namely static and rolling. The specimens for the static tests consisted of 2 blocks of matched material. The top of the lower block, or base, was a carefully finished plane surface. The lower face of the upper block, or segment, was a carefully finished cylindrical surface. The bases and segments were from 10 to 12 inches high and 10 to 16 inches long. The two blocks constituting a pair had the same width; the width for various pairs ranging from 0.87" to 12.0." A study was made of the effect of the diameter, width of specimen, type of material (whether steel casting or steel

forging), and the hardness of the material as controlled by composition or by heat treatment. The diameters for this series varied from 120 to 720 inches.

"The results of numerous tests upon different materials show that a formula for the load that produces set is of the form $P = A + kD$, where P is the load in pounds per linear inch of cylinder, D is the diameter of cylinder in inches, and A and K are constants for a given material. The tests indicated that for diameters of 40 to 120 inches, the height of base did not appreciably affect the load causing a yield point stress in the material; but for a diameter of 480 inches decreasing the height of base below 5 inches caused a gradual decrease in the load producing a yield point stress. The results of three series of tests upon the effect of width of segment indicated that the load producing set increased with the width of the specimens up to 6 inches but that an increase in width above 6 inches did not materially increase that load.

"The hardness of the specimens affected the load producing set very greatly. An increase in the Brinell hardness number from 105 to 165 caused a rapid increase in the load producing set, the rate of increase being very much slower as the Brinell number increased to approximately 190. Beyond this point, the load producing set remained constant or actually decreased as the hardness of the material increased.

"The rolling test series was planned to determine if a relation exists between the load that produces set for static tests and the load that causes a progressive elongation of the plate for

rolling tests. The plates for this series were of medium grade steel, 4 inches wide, 12 inches long and varied from $1/8$ to 4 in. in thickness. The segment was 4 inches wide, 16 inches long, 6 inches in depth, and of hardened nickel steel, its bottom face being ground to a perfect cylindrical surface. Diameters studied in this series varied from 65 to 476 inches.

"The results of a limited number of tests show that the load that causes a progressive elongation of plate increases as the thickness of the plate, for any given diameter. An increase in diameter for any given plate likewise causes a proportional increase in this load. The loads that produced progressive elongation of the plate for diameters of 16, 30 and 40 feet rolling on 2 inch plates checked the results of static tests on medium grade steel castings very closely."

Tests performed since 1927 were planned to study the effect of (1) thickness of plate, (2) diameter of roller, (3) kind of material, and (4) heat treatment to which the material was subjected upon the load producing progressive elongation.

All specimens were plates having solid rectangular sections 4 inches wide and 12 inches long. They varied in thickness from $1/4$ inch to 4 inches. The rollers varied in diameter from 116 inches to 476 inches. Most of the plates were steel castings of medium grade but a number were hot rolled steel of structural grade and two were manganese steel castings. Most of the specimens were annealed before being tested but a few were hardened by heat treatment.

The tests indicate that the minimum load producing progressive flow increases with the diameter of the roller. The equation of the line representing the relation between longitudinal flow and load for medium grade steel castings, is $P = 22,000 + 87D$, where P is the load per inch width of plate and D the diameter of the roller in inches. The relation between lateral flow and load is represented by a line whose equation is $P = 20,000 + 97D$.

The relation between the load producing longitudinal flow and the thickness of plate can be expressed by a straight line formula but the load producing lateral flow increases, reaches a maximum and then decreases.

The material from which the specimens were made affected the critical load greatly. Even two materials supposedly alike gave quite different results.

The bearing capacity of low carbon steel can be increased by heat treatment.

The formula recommended by Professor Wilson for determining the safe loads on rollers is $P = \left(\frac{p - 13000}{13000} \right) (12000 + 80D)$, where P is the safe load in pounds per inch width of plate, D is the diameter of roller in inches and p is the yield point strength of the material in tension in pounds per square inch.

6. Experiments of Brown and Hartmann. Both static and rolling tests were made on rollers from 8 inches to 20 inches in diameter. The static tests were designed to study the effect of diameter and hardness of plates. All the specimens were 2 inches wide. The rolling tests were made on rollers from 4 inches to 12 inches in diameter to study the effect of diameter and the force required to

produce action. The specimens were all cut from the same block of medium grade steel casting and were 4 inches wide.

The static tests indicate that the relation between the critical load and the diameter is expressed by an equation of the form $P = A + kd$. Due to erratic results no relation was set up.

In tests where the hardness of base and cylinder were not the same, the critical load depended only on the softer material. In tests on plates of varying hardness, the critical load increased with an increase in the Brinell number to about 120, then remained about the same or decreased. This relation was also found in Professor Wilson's tests on large rollers.

The relation between the critical load and the diameter is expressed by a formula of the type $P = (A + kD) \sqrt[3]{D}$.

III. DESCRIPTION OF APPARATUS
AND INSTRUMENTS.

III. DESCRIPTION OF APPARATUS AND INSTRUMENTS.

1. Apparatus for Testing Large Rollers. The apparatus for testing large rollers was the same as that used by Professor Wilson in his study of the bearing value of rollers and is shown by diagram in Fig. 3 and by photograph in Fig. 4. It consisted of 2 main parts:

(a) A built up radius arm suspended from a roller bearing which in turn was suspended from the head of the testing machine. A segment of a cylinder of the proper radius was attached to the lower end of the arm, this being the roller to be tested.

Preparatory to conducting a test, the segment was refinished by grinding with a motor-driven emery wheel. This process insured the axis of the cylinder coinciding with the axis of the roller-bearing.

(b) A movable carriage driven by an electric motor. The carriage was supported by three $6\frac{1}{2}$ -inch hardened steel rollers. The specimen plate rested on top of the carriage as shown in Fig. 3. A hardened steel plate resting on the bed of the testing machine provided a smooth surface for the supporting rollers to roll on.

The relation of various parts is shown in Fig. 3. The radius arm can be varied in length from 18 inches to 20 feet.

The grinding preparatory to rolling was accomplished by swinging the segment back and forth over the grinding wheel which in turn was moved across the face of the segment parallel to the axis of the roller. Many methods of mounting the wheel were

devised. One is shown in the photograph in Figure 4.

The driving mechanism consisted of an electric motor, a gear train and a crank. The speed of the crank was 30 revolutions per minute making 60 strokes of the roller per minute. The throw of the crank or travel of the roller was 8 inches.

2. Apparatus for Testing Small Rollers. The apparatus used for large rollers seemed adaptable to the study of small rollers. A few alterations were necessary. The apparatus is shown by the diagram of Fig. 5 and the photograph of Fig. 6. It consisted of 2 main parts:

(a) A built up radius arm suspended from a roller bearing which in turn was suspended from the head of the testing machine. A segment of a cylinder of the proper radius was attached to the lower end of the arm. Any convenient radius arm would serve in this apparatus. The purpose of this cylinder was to transmit the load to the movable carriage. It is desirable to have the radius fairly large in order to require a small force from the driving mechanism. In these tests the radius was 58 inches.

(b) A movable carriage driven by an electric motor. The carriage was supported on the specimen roller to be tested which in turn was supported by the specimen plate.

To secure stability, two 8 inch channels were bolted to the carriage as shown in Fig. 5. The outer ends of these channels were carried by a small roller mounted on a table which transmitted its load to the floor and not through the testing machine. The load measured by the ^{testing} machine was the load carried by the specimen

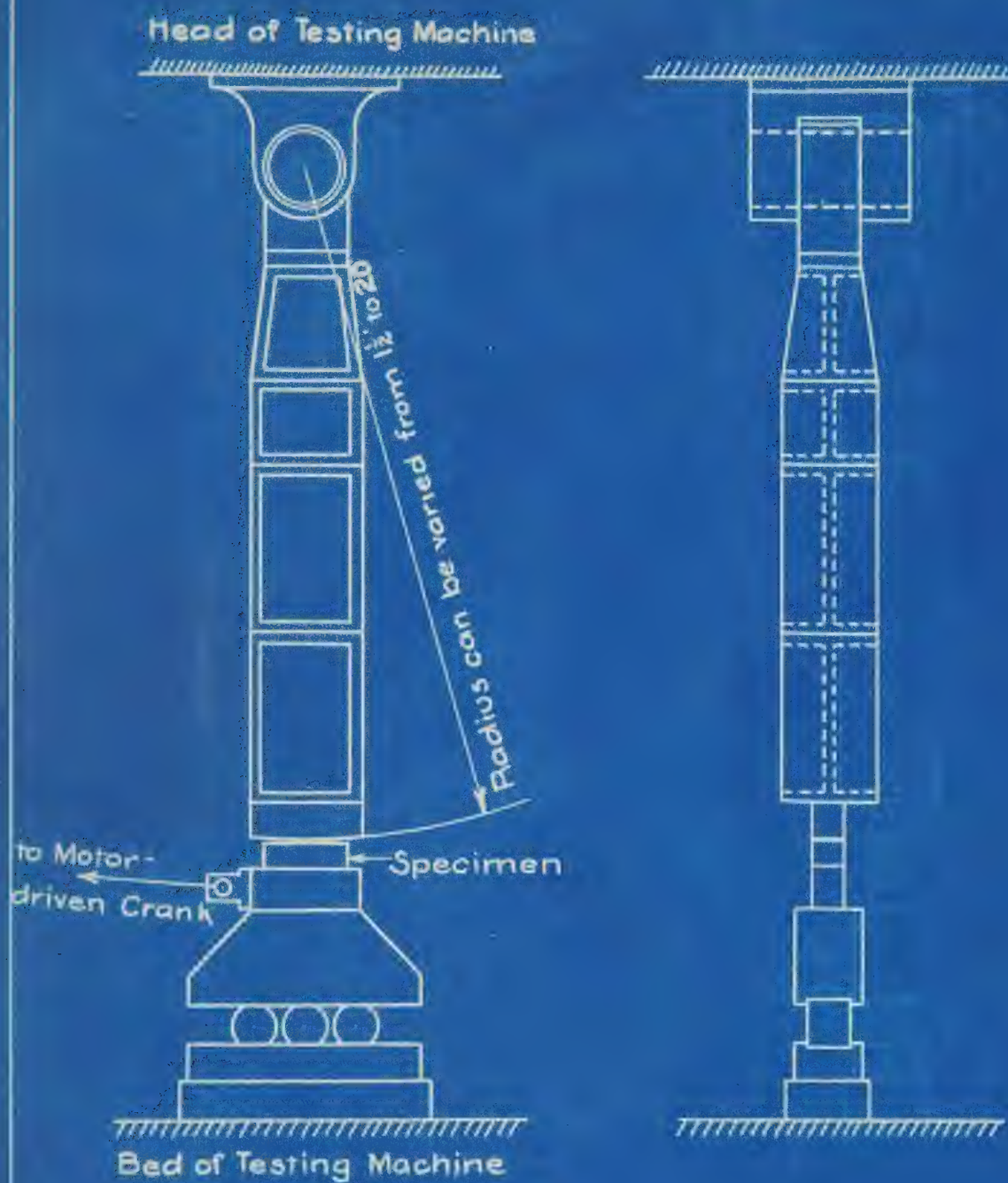
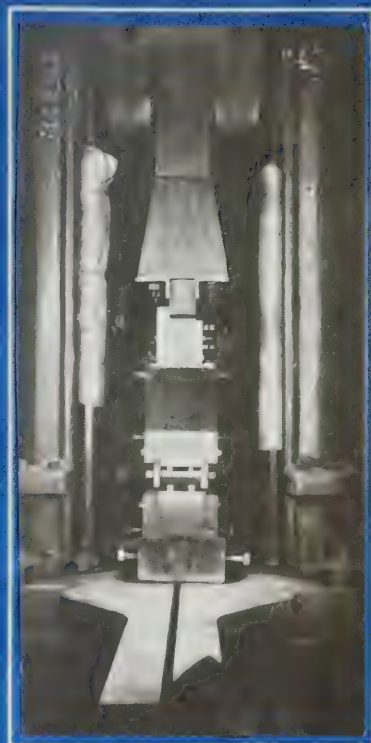


Fig. 3
Diagram of Apparatus for Testing Large Rollers



Grinding Wheel



Specimen in Place



Driving Mechanism

Fig 4
Apparatus for Testing Large Rollers

roller. It was necessary to keep the line of pressure of the testing machine between the specimen roller and the small auxiliary roller supporting the ends of the channels. Since the line of pressure remained at the center of the testing machine, it is obvious that the load on both rollers would vary during the travel of the carriage if the top of the carriage remained perfectly horizontal. In order to keep the load on the specimen roller constant, the bearing block on top of the carriage was shimmed up at one end until the load on the specimen remained constant throughout the travel of the carriage.

The driving mechanism was the same as used in the apparatus for testing large rollers.

The carriage and roller had to be lifted in order to get the plate in its place. The carriage was lifted by fastening it to the radius arm by means of hooked bolts and raising the head of the testing machine. The bottom ends of the bolts were threaded for nuts so they could be loosened during the process of rolling and tightened before the load was removed so the slack would not have to be taken up by raising the head of the machine.

The rollers larger than 8 inches in diameter were too heavy to lift by hand; so they were hooked to the carriage and raised with the head of the machine.

The arrangement of hooks is shown by the photographs of Figure 6.

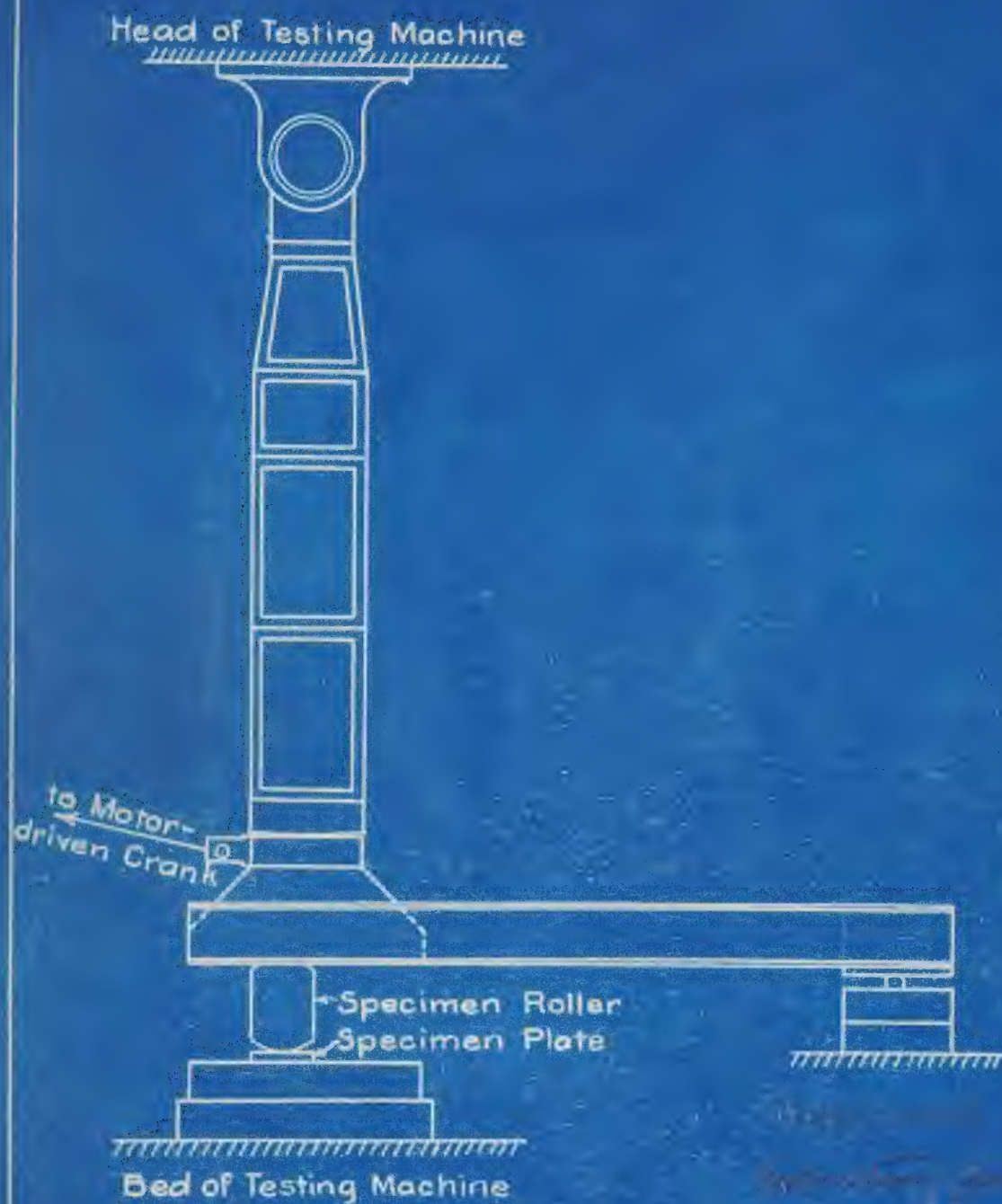
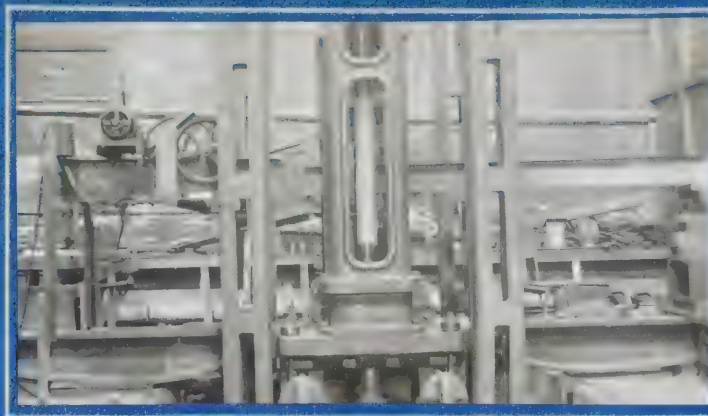


Fig. 5
Diagram of Apparatus for Testing Small Rollers



General View of Apparatus



Specimen in Place



Hooks for Raising Carriage

Fig 6.
Apparatus for Testing Small Rollers

3. Description of Instruments. The measuring instruments used during these tests are shown in Figure 7.

The micrometer is a Brown and Sharpe instrument. One division on the scale indicated 0.001 of an inch and tenths of a division were read on a vernier on the micrometer spindle.

The strain gage is of the Berry type using a 2 inch gage length. It is provided with an Ames dial graduated to thousandths of an inch movement of the plunger. The multiplication ratio is five making one division of the dial represent 0.0002 of an inch. Tenths of a division on the dial were estimated.

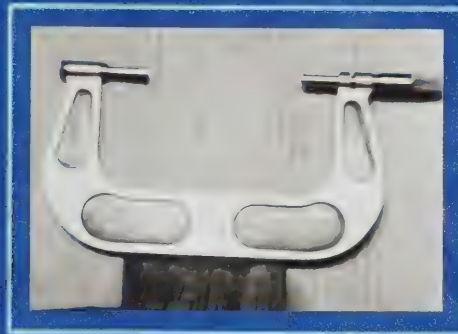
An instrument devised for making the measurement of elastic lateral flow of the plate is here called the yoke. It consists of a U-shaped yoke which has a pointed, adjustable screw in one leg and a micrometer dial mounted on the other. A flexible arm mounted on the leg carrying the dial is provided with a hardened steel point in line with the plunger of the dial. The points on the adjustable screw and flexible arm engage holes drilled with a number 54 drill $1/8$ of an inch from the surface of the plate. The dial is of the Last Word type in which one division of the dial represents 0.0001 of an inch movement of the plunger. Divisions on the dial were estimated with an accuracy of perhaps plus or minus two tenths.



Strain-Gage
For Measuring
Longitudinal Flow



Yoke
for Measuring Elastic
Lateral Flow



Micrometer
For Measuring Lateral Flow

Fig. 7
Instruments
For Measuring Strains

IV. DEVELOPMENT OF METHOD OF
TESTING.

IV. DEVELOPMENT OF METHOD OF TESTING.

1. Description of Specimens. A preliminary test was made on a roller $4\frac{1}{2}$ inches in diameter bearing on a plate 1 inch by 4 inches by 8 inches. The roller was 4 inches long in the direction of its axis. Both the roller and plate were machined from steel of structural grade taken from the stock in the laboratory. The surfaces were finished with a file and emery cloth and proved with a machinist's face plate.

2. Measurements Made. Measurements were made to determine:

(a) Permanent lateral flow of the plate. The lateral flow was determined by measuring the width of the plate before and after rolling, the load being removed while the readings were taken. The difference in the width is the lateral flow of the plate in 4 inches. The unit lateral flow or flow in inches per inch of width is plotted in Fig. 8. Measurements were made $1/8$ of an inch from the top and bottom and at the mid-height of the plate.

(b) Elastic lateral flow of plate. The yoke was used for measuring the elastic lateral flow. It was mounted on the plate and the dial reading observed while the roller was in motion. The difference between the readings when the roller was at the end and middle of the stroke is interpreted to be the elastic flow of the plate.

(c) Permanent longitudinal flow of the plate. The difference in strain gage readings of the unloaded plate before and after the plate had been rolled is the total longitudinal flow in 2 inches.

The unit longitudinal flow is plotted in Figure 9. Measurements were made 1/8 of an inch from the top and bottom and at the mid-height of the plate.

(d) Change in diameter of roller. The change in diameter of the roller was determined by measuring the diameter with the micrometer before and after rolling. The change of diameter is plotted in Figure 10.

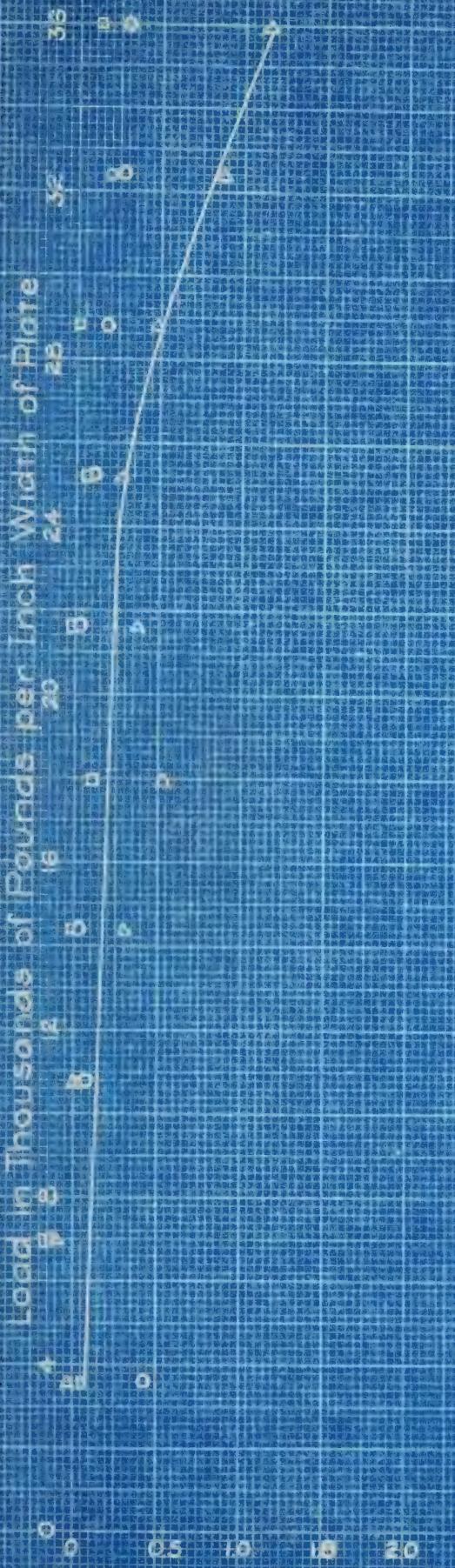
(e) Spread of roller. The spread of the roller was determined by measuring the length of the roller with the micrometer in the direction of its axis before and after rolling. The unit spread of roller is plotted in Fig. 11.

3. Description of Test. After a complete set of measurements had been made, the specimens were rolled under a load of 200 LD or 3600 lb., L being the length of the roller in the direction of its axis and D the diameter in inches. Measurements were taken at the end of about 30, 60, 120, 250, 500, 1000 and 2000 strokes to determine the strains in the specimens. The load was then increased 3600 pounds and the process repeated. The test was thus continued, the load increasing by increments of 3600 pounds, up to a final load of 2000LD. The results of this test are presented in Figures 8, 9, 10 and 11.

4. Conclusions from the Preliminary Test. The following conclusions were reached:

(a) The maximum lateral flow occurred at the top of the plate, the flow at the middle and bottom being almost negligible as indicated in Figure 8a. The readings were easily duplicated and

Fig. 6a
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 4.5
Preliminary Test



Legend
 Flow at Top **A**
 Mid-height **B**
 Bottom **C**
 Steel of Structural Grade
 Width of Plate 4
 Thickness of Plate
 Brinell No. 130

Fig. 8b
 Lateral Flow of Plate
 Due to Rolling
 Diameter of Roller 4 ft
 Preliminary Test
 Scale 1/10,000

Steel of Structural Grade
 Thickness of Plate 1/2
 Width of Plate 4
 Brinell No. 30

Number of strokes in hundred

10000

20000

30000

40000

50000

60000

70000

80000

90000

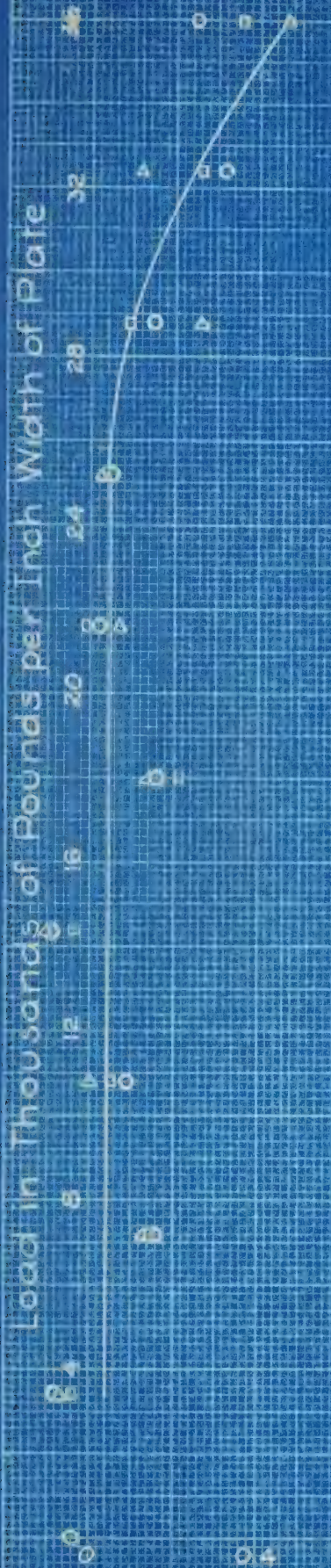
100000

Unit: Horizontal Flow

Fig 9a

Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 4 1/2"
Preliminary Test

Load in Thousands of Pounds per Inch Width of Plate



Legend:

Flow on Top Δ

Middle $\circ$

Bottom $\square$

Steel of Structural Grade

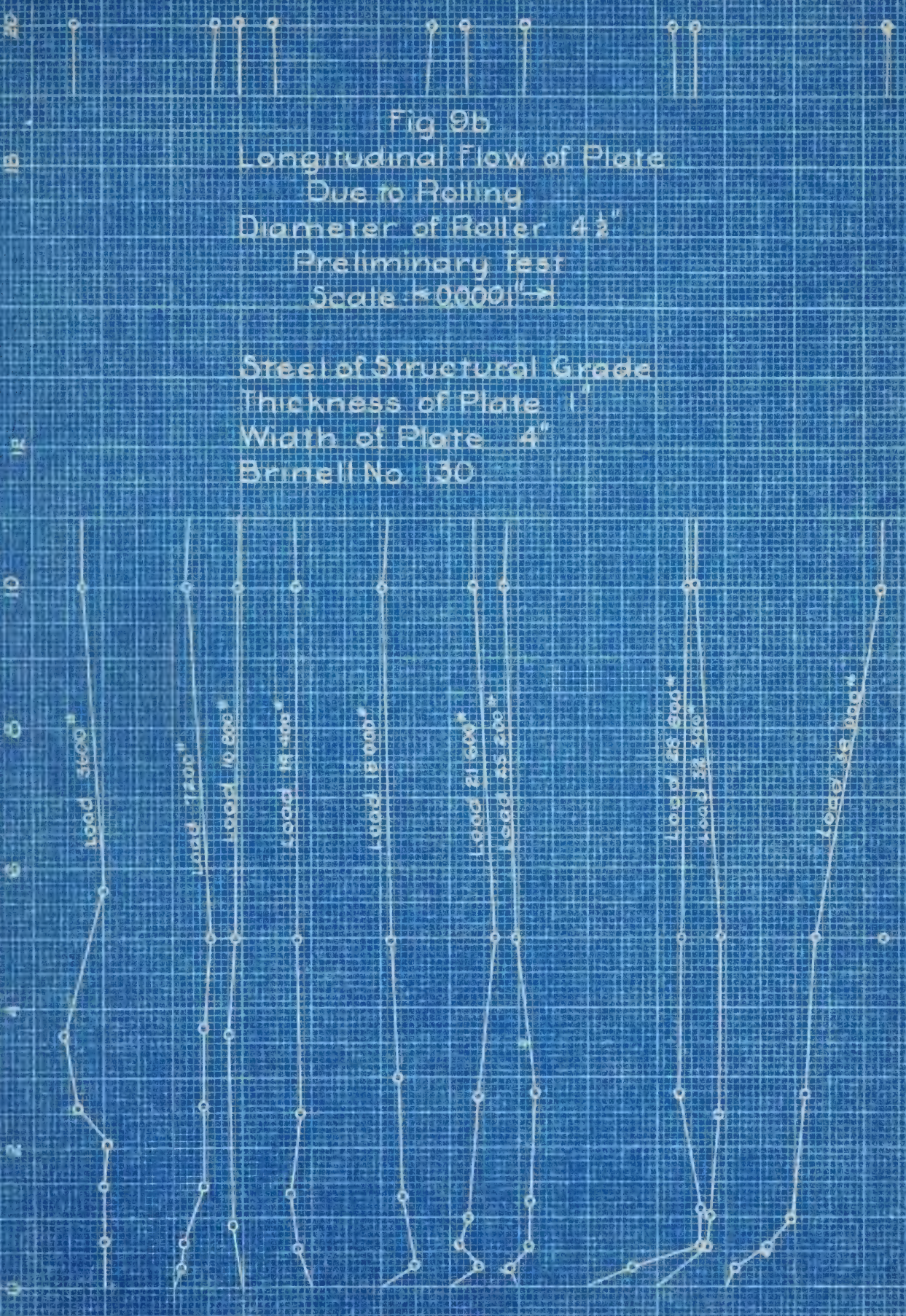
Width of Plate 4"

Thickness of Plate 1"

Brinell No. 130

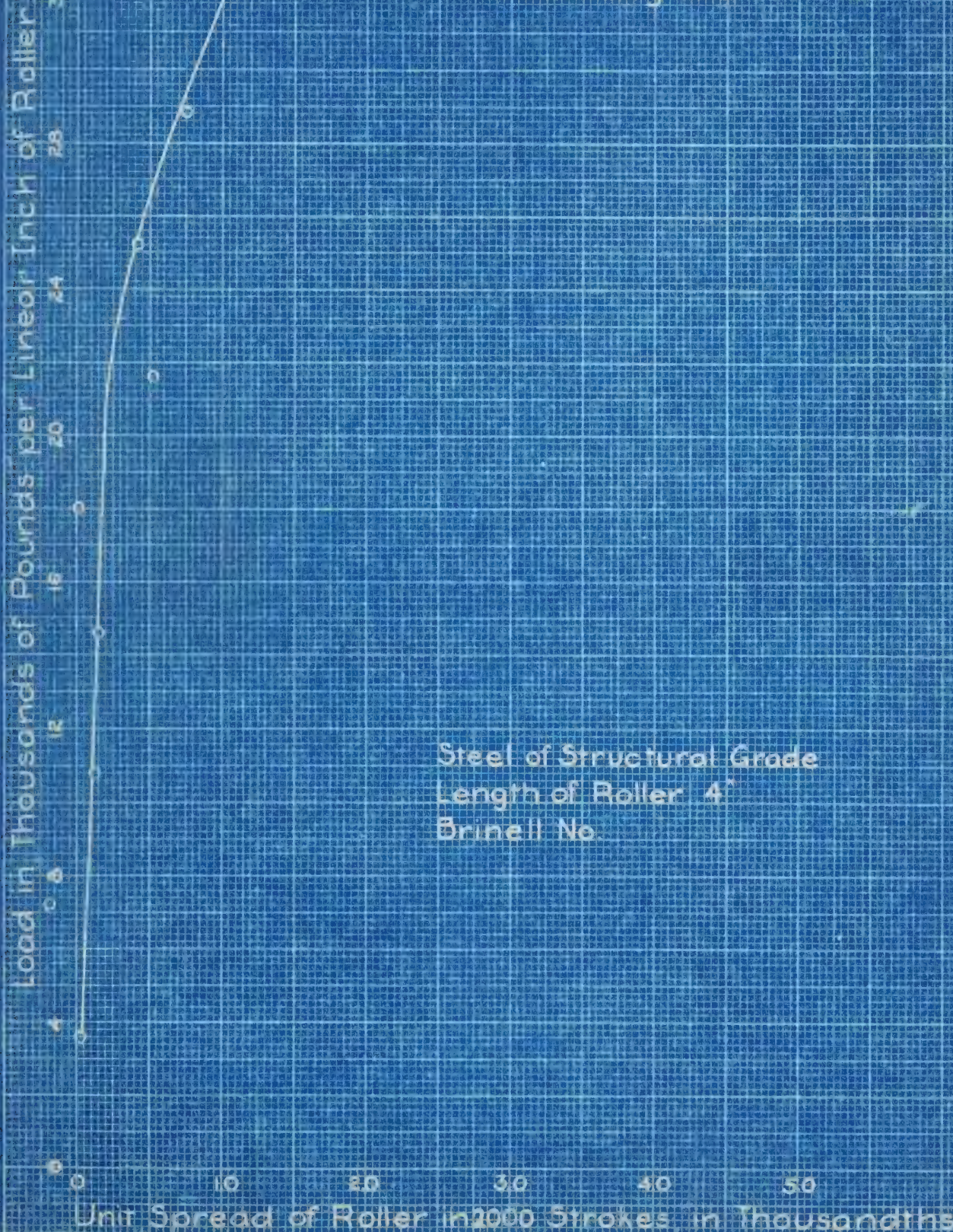
Unit Longitudinal Flow in 1000 Strokes in Thousandths

Number of Strokes in Hundreds



Unit Longitudinal Flow

Fig. II
Spread of Roller
Due to Rolling
Diameter of Roller 42
Preliminary Test



seemed to be a good index of the behavior of the material.

(b) The measurements for the elastic lateral flow of the plate did not prove to be of sufficient value to warrant the time required to take them, although the readings were easily duplicated.

(c) Measurements for the change in diameter were not worth taking. The readings were very difficult to make because it was impossible to place the micrometer on the same points each time as rolling obliterated any marks on the surface.

(d) The curve showing unit spread of roller is very similar to that showing unit lateral flow of plate.

(e) The flow of metal does not continue with rolling. The flow at the end of 100 strokes is about the same as at the end of 2000 strokes.

V. DESCRIPTION OF TESTS.

V. DESCRIPTION OF TESTS.

1. General. The tests constituting this investigation were performed on the same plan as the preliminary test. Each specimen was rolled a total of 1000 strokes and measurements were taken at the end of 100, 500, and 1000 strokes.

Since it was desired to tie the results of this series of tests to a series on rollers larger than 116 inches in diameter that had been performed by Professor Wilson, this series was made as nearly like Professor Wilson's series as possible. It was found in tests on large rollers that a variation in the quality of the material and thickness of plate caused a variation in the bearing value of the roller. There were in the laboratory some steel castings 4" x 12" x 36" from the same heat as the one tested by Professor Wilson. The same thickness of plate was used in the two series.

Measurements of the permanent lateral and longitudinal flow of the plate and spread of roller were thought sufficient to detect progressive flow when it occurred.

2. Description of Specimens. The casting from which the specimens of this series were cut was one of a number in the laboratory from the same heat. Some were honeycombed with blow holes but this one seemed to be free from such defects. The chemical analysis shows the following properties: C, 0.283; S, 0.043; Si, 0.046; Mn, 0.496.

Originally the casting was 4" x 12" x 36". After being cut

into two pieces, one 4" x 12" x 12" and the other 4" x 12" x 24", it was annealed by heating to a temperature of about 1450 degrees F, holding at that temperature for about six hours and cooling in the furnace, both pieces being treated at once.

All the plates and small rollers were cut from this casting. The segments for the cylinders of the large rollers were cut from plates that had been tested in a study of large rollers and were from a similar casting. Figure 12 shows the location of each plate in the original casting.

Specimens H1 to H6 inclusive were 1½" x 2" x 8", H7 and H9 were 1½" x 4" x 6" and H10 to H14 inclusive were 1½" x 4" x 12". The specimens were machined in a shaper, the rolling surfaces being finished by hand with a file and emery cloth and proved with a machinist's face plate.

In some cases where the deformation of the plate at the bottom was very small, the block was turned over, finished on the bottom and tested again. The second test is designated by an additional letter A so that H3 finished on the bottom became H3A.

The small rollers were cut from a portion of the large piece of the casting. Since the travel of the carriage was 8 inches, a full cylinder was not necessary in most cases. The block from which the rollers was turned was 4" x 8" x 24". After each individual test, the rolled portion of the roller was cut off with the hack saw. Tension test specimens were cut from the piece removed. The roller was then turned to the next smaller cylinder. Figure 13 shows the location of each roller in the block.

The physical properties of the material are given in Table 1.

They were determined for the rolled and unrolled portions of the plate. The specimens taken from the rolled portion of the plate were located $\frac{1}{2}$ " from the lateral centerline and the specimens from the unrolled portion were taken $\frac{1}{2}$ " from the end of the plate.*

3. Procedure of Testing. The specimens were placed in the machine and centered with respect to the plane of rolling. After a load was put on the roller, thickness gages were placed between the segment and plate. If they were parallel, it was assumed the pressure was uniformly distributed across the specimen. If the gages were not parallel the bearing plate was shimmed up on one side until they were. The load on the roller was measured at the middle and ends of the stroke. If it was not constant, adjustment was made by shimming under one end of the bearing plate until it was constant.

With the apparatus in adjustment and the initial measurements made, the load was applied by the testing machine. It usually dropped several hundred or a thousand pounds with the first few strokes, so it was watched closely and brought back to the original value. After the desired number of strokes had been made, the load was removed and the specimens were measured. The load was then increased, the increment varying with the size of roller. Readings were again taken after 1000 strokes. This process was repeated, the load being increased until a considerable flow had occurred.

The Brinell tests for hardness were made on the rolled and unrolled portion of the plate and segment.

The tensile test for physical properties was made on standard

*Physical properties of rollers will be found on page 206.

Block from which Rollers were turned					H9	H10	H11	H12	H13	H14
H2			H4		H6		H7			
H1			H3		H5					

Fig. 12
Diagram Showing Location of
Specimens in Original Casting.



Fig. 13
Diagram Showing Location of Rollers
in Original Block

Table I
PHYSICAL PROPERTIES OF PLATES

Bearing Value of Small Rollers

Specimen	Before Rolling					After Rolling				
	Ultimate Strength	Yield Point	Elongation in 2 inches	Reduction of Area	Brinell Number	Ultimate Strength	Yield Point	Elongation in 2 inches	Reduction of Area	Brinell Number
H1	64,410	30,960	31.00	40.72	128	65,820	37,440	24.50	30.31	147
H2	63,142	33,050	29.75	39.81	129	64,260	34,320	26.00	34.62	147
H3					141					159
H3A	64,500	31,880	27.25	36.39	128	65,030	34,640	27.87	38.76	151
H5					118					134
H5A	64,870	32,790	31.87	46.33	130	65,160	33,410	20.81	46.30	157
H7					128					165
H7A	64,630	32,060	30.75	38.12	132	63,600	32,890	28.00	29.38	185
H9	64,660	33,600	26.50	45.41		44,730	31,680	5.37	19.69	
H10										
H11	63,950	30,800	28.25	28.97	130	64,710	35,340	22.50	26.82	139
H12	64,130	30,920	28.12	33.16	129	64,490	34,590	26.50	31.17	139
H13	64,210	30,760	27.19	38.84	125	64,180	33,160	27.12	40.76	136
H14	65,700	31,500	27.75	39.69	128	64,310	33,660	28.00	38.84	138

tensile specimens $\frac{1}{2}$ inch in diameter and 4 inches long. The yield point stress was determined by the drop of the beam. The percentage elongation was measured on a gage length of 2 inches on diametrically opposite lines. The ultimate stress is calculated as the breaking load divided by the original area.

VI. INTERESTING PHENOMENA.

VI. INTERESTING PHENOMENA.

1. Surface Effects. At the beginning of each test, the bearing surfaces were perfectly smooth and shiny. As the heavier loads were rolled, the surfaces became covered with a sort of black dust which was easily wiped off.

2. Flow of Material. The first evidence of flow of material was the sharpening of the corners of the plate. In most cases the flow increased until it became detectable to the touch. The photographs of Figure 14 show some cases of excessive flow. The reason for there being no noticeable flow at the top of the roller on H9 shown in the photograph is that the roller had to be kept filed down to roll between the guides on the carriage. However, the flow at the bottom of the roller is quite noticeable. In the photograph showing lateral flow of plate, the sides of the plates are curved. Before testing, the sides of the plate were straight and parallel. Sents for the Brinell Hardness test can be seen in one plate. The surface of the plate shown in the upper right photograph was perfectly smooth before testing.



Spread at Bottom
of Roller



Surface of Plate
After Rolling



Lateral Flow of Plate

Fig 14
Photographs of Specimens
After Testing

VII. RESULTS.

VII. RESULTS.

1. Criterion for Determining Critical Load. The relations between load and flow are shown in the accompanying figures. If the load-deformation curve contains a sharp break, the load at which the break occurs is the greatest load that can be rolled without producing excessive flow and hence should govern the design of plates and rollers.

The curves showing the relation between load and lateral flow and between load and spread of roller do not contain a definite break. The critical load is, therefore, considered to have been reached when the unit flow became 0.001 inches per inch in 1000 strokes.

The curves showing the relation between load and longitudinal flow are of three general types. The first type has a definite break in the relation of load to flow as at point a Figure 20 b. The critical load is interpreted to be that at the break in the curve. Another type of curve, as shown in Figure 23 b, has a reversal of curvature. The critical load is interpreted to be that at the point of reversal indicated by the letter a. The third type of curve, as shown in Fig. 26b, has neither a sharp break nor a reversal of curvature. The curve indicates that the critical load for longitudinal flow has not been reached. Perhaps either a reversal of curvature or break in the curve would have been obtained if the test had been continued at higher loads.

2. Individual Tests. The plates used in these tests were all cut from the same steel casting after it had been annealed. All

plates were 4 inches wide and 1.5 inches thick. All plates except H14 were rolled under segments made of annealed steel castings similar in properties to the plates. The plate H14 was tested under a segment made of hardened nickel steel. Details of the various tests are given in the following paragraphs. The physical properties of the material are given in Table 1.

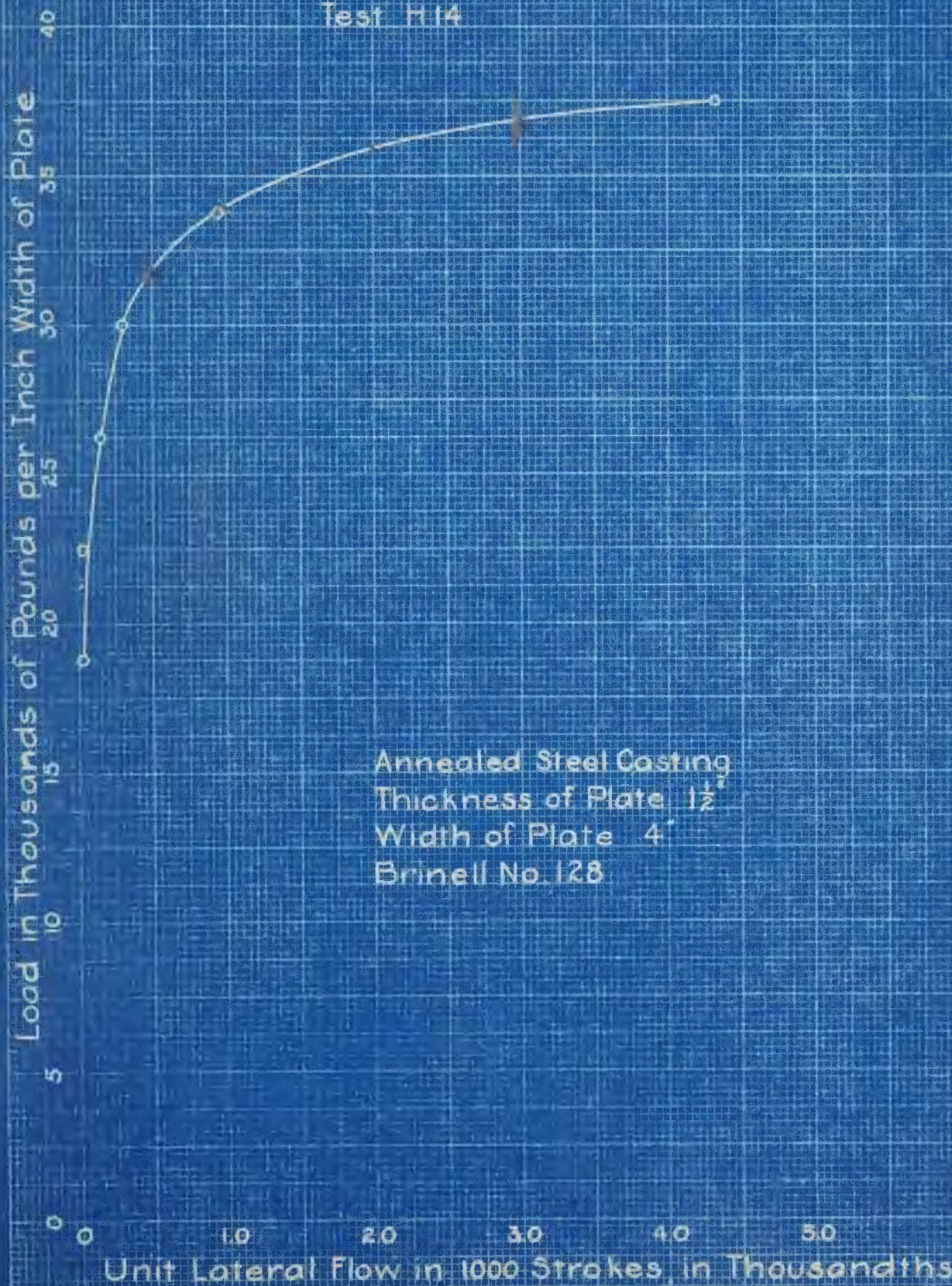
11 1/2. In. Roller of Hardened Steel on H14. The tests on large rollers with which this work is to tie in were made with hardened steel rollers. In order to determine the effect of the hardness of the roller on the bearing value of the plate, one specimen was roller under a hardened roller.

The load-deformation curves for this test are given in Figure 15.

The critical load determined by lateral flow is 34,000 pounds per inch width of plate.

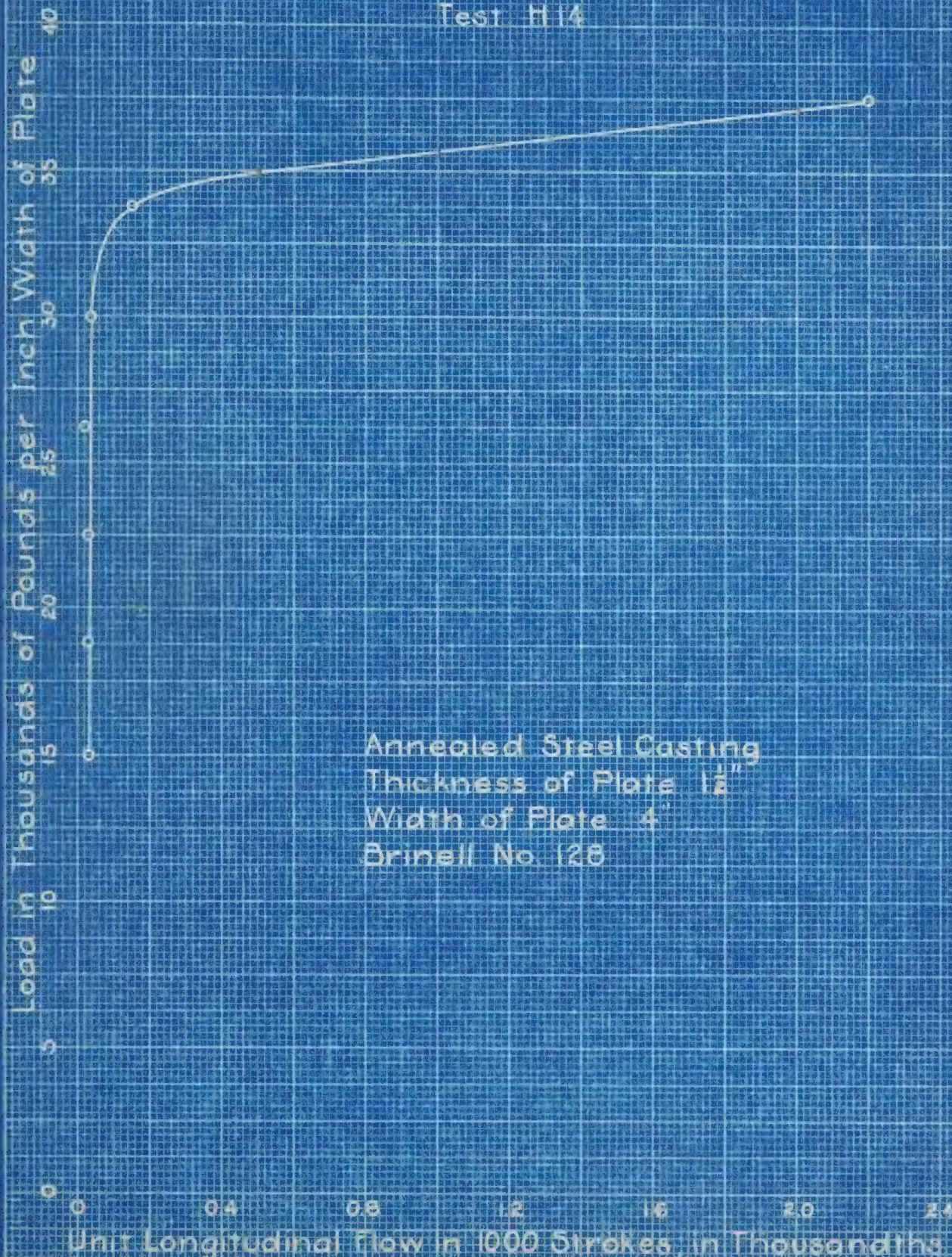
The critical load determined by longitudinal flow is interpreted to be at the break in the curve and is equal to 33,000 pounds per inch width of plate.

Lateral Flow of Plate
Due to Rolling
Under Hardened Steel Roller
Diameter of Roller 116"
Test #14



Annealed Steel Casting
Thickness of Plate 12
Width of Plate 4
Brinell No 128

**Longitudinal Flow of Plate
Due to Rolling
Under Hardened Steel Roller
Diameter of Roller 16"
Test: H14**



116 in. Roller on H10. The load-deformation curves for this test are given in Fig. 16. The critical load determined by lateral flow is 34,500 pounds per inch width of plate.

The critical load determined by longitudinal flow is interpreted to be the load at the break in the curve and is 33,300 pounds per inch width of plate.

The curve for spread of roller does not indicate^a critical load.

The greater hardness of the roller has no effect on the bearing value of the plate, as shown by the results of this test compared with the results of the test on H14.

Lateral Flow of Plate Due to Rolling Diameter of Roller: 116" Test H10

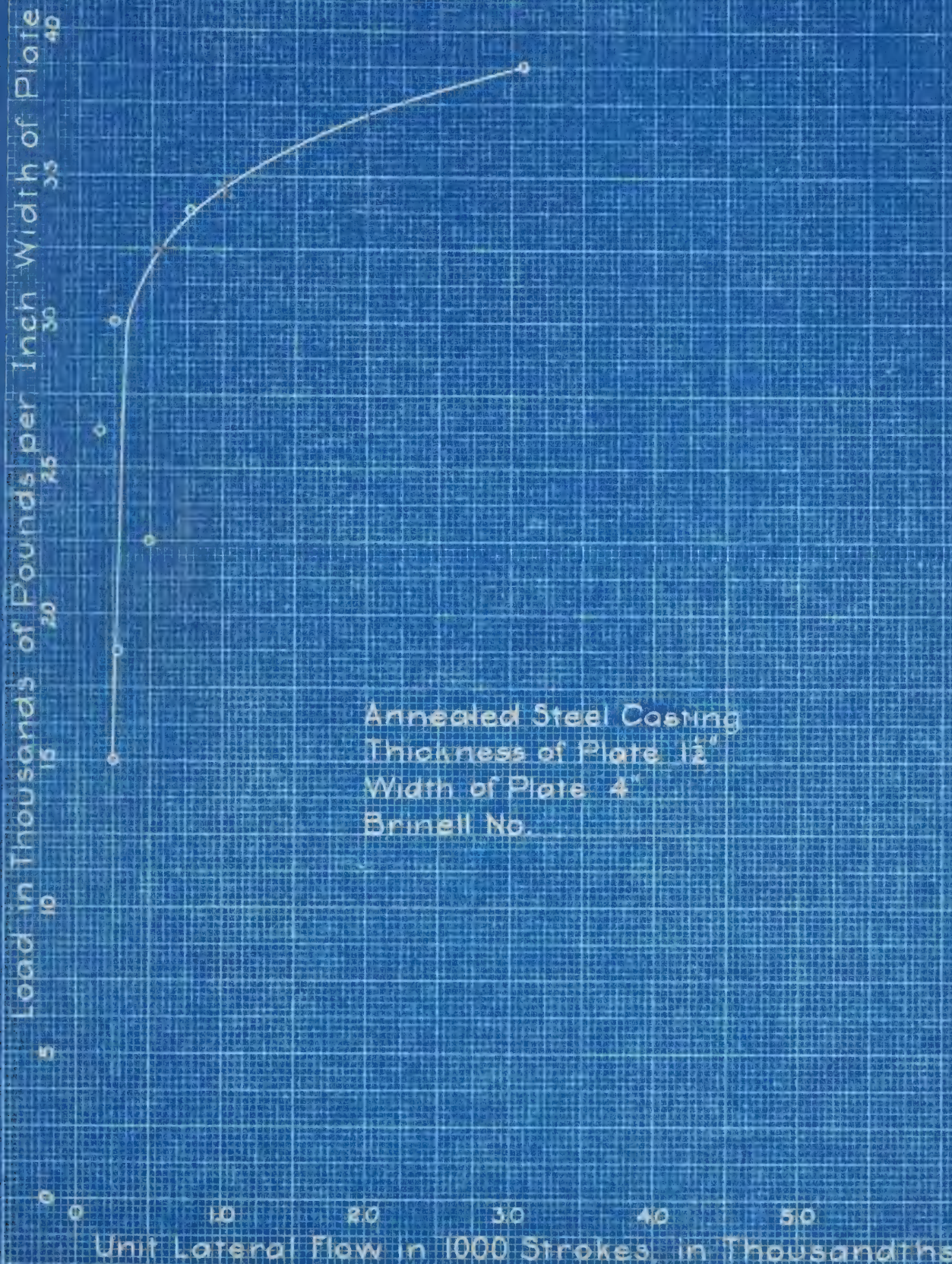


Fig. 16 b

Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 16"
Test No. 10

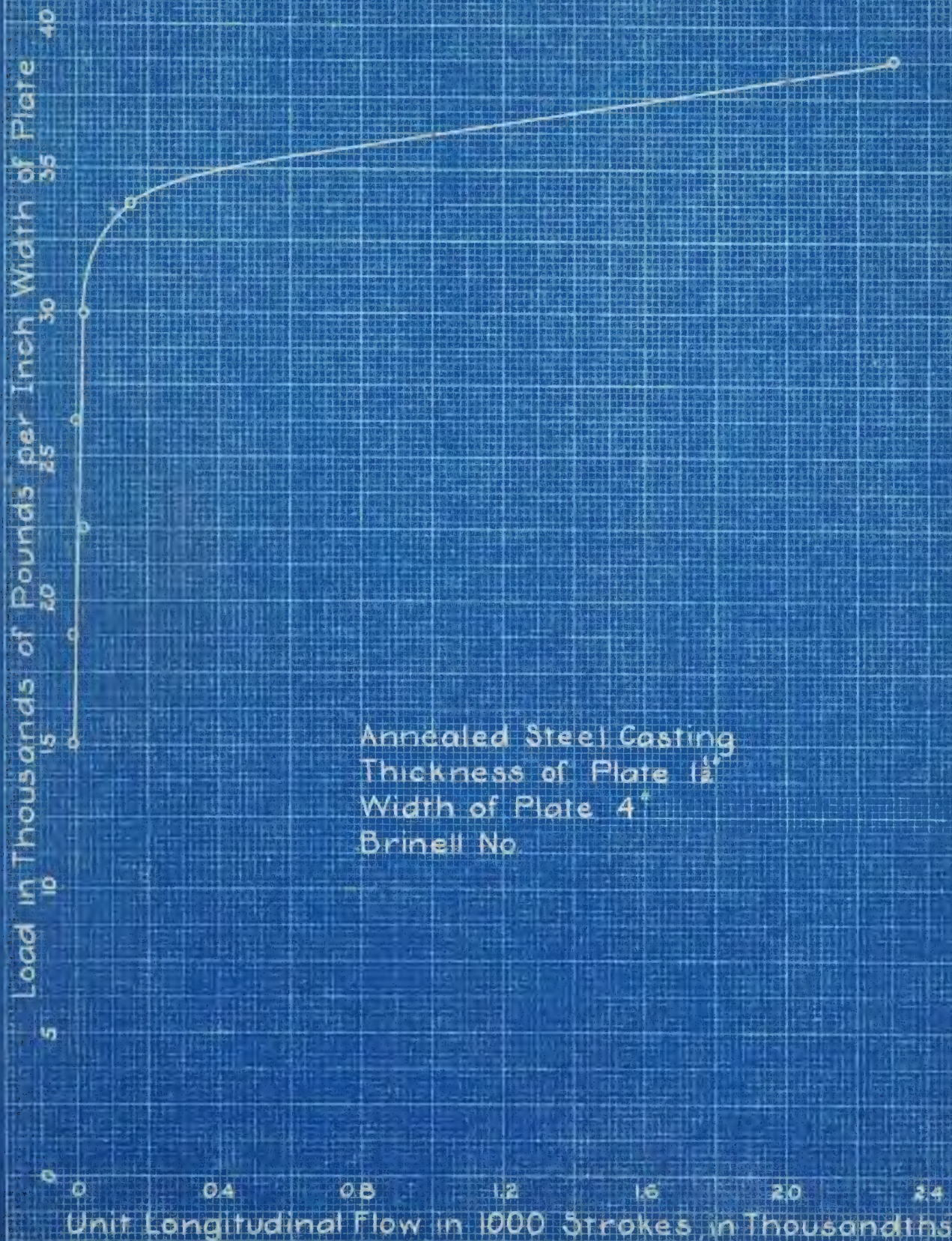
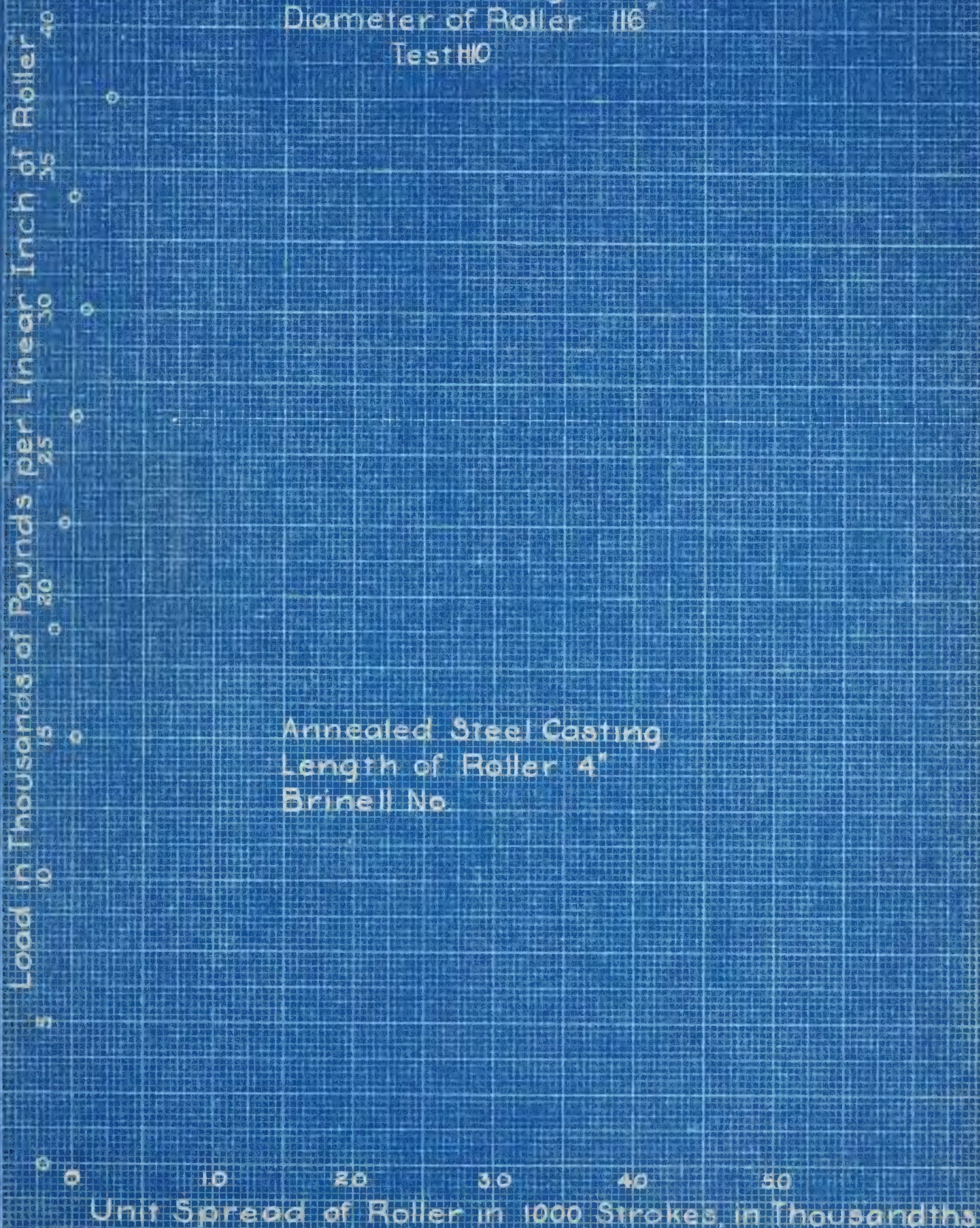


Fig 16c
 Spread of Roller
 Due to Rolling
 Diameter of Roller 116
 Test NO



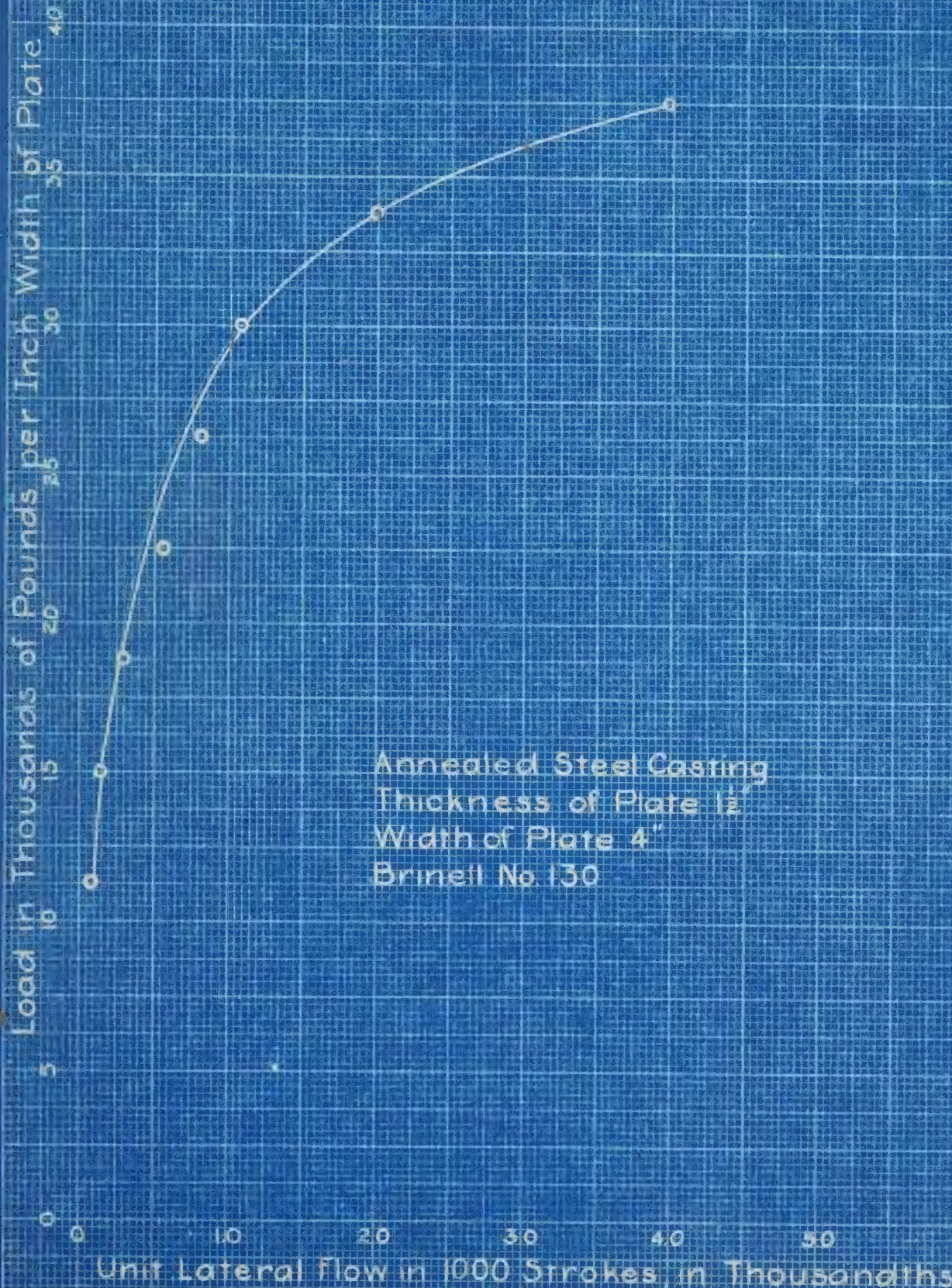
92 inch Roller on Hll. The load-deformation curves for this test are given in Fig. 17.

The critical load determined by lateral flow of plate is 28,300 pounds per inch width of plate.

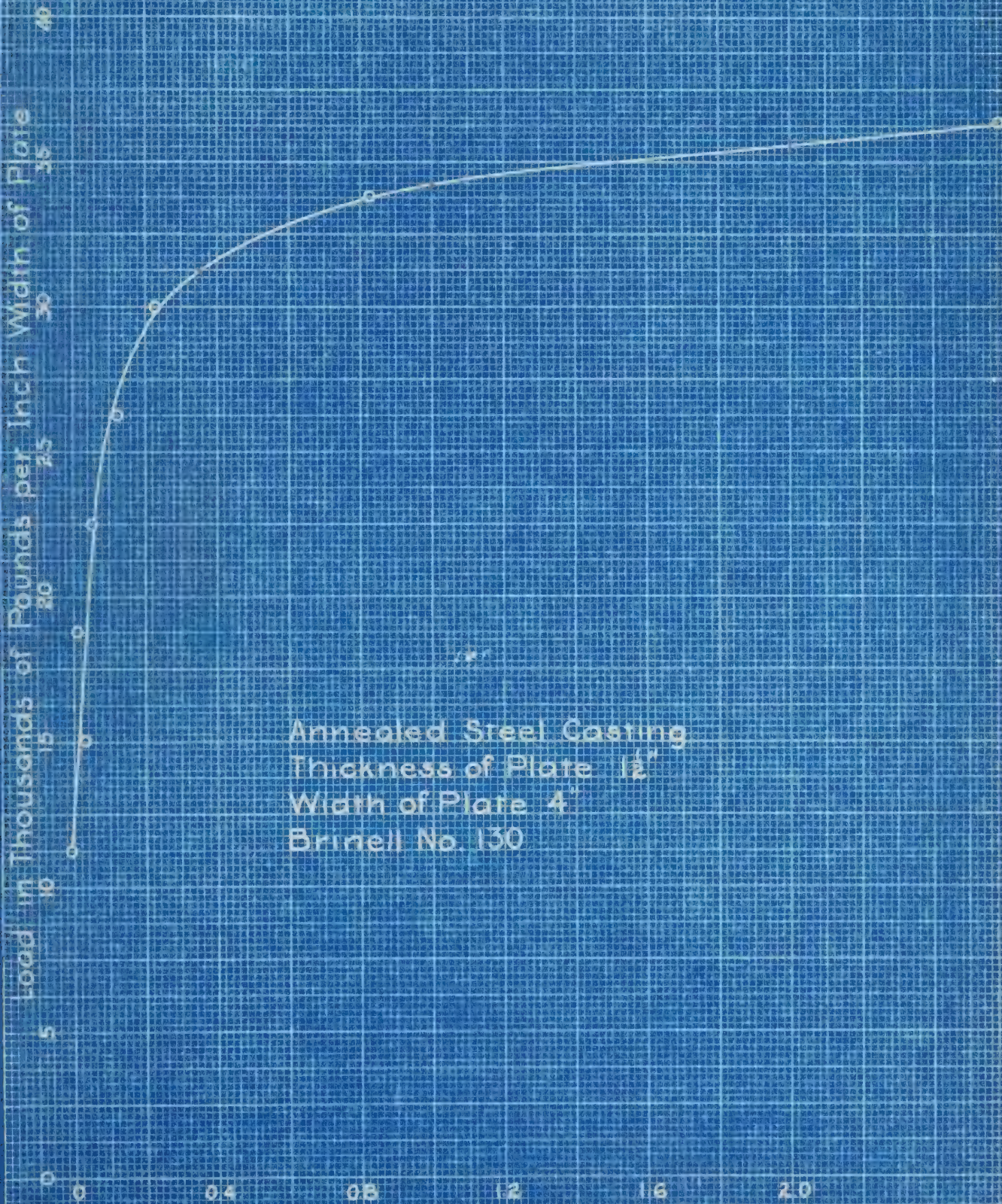
The critical load determined by longitudinal flow of plate is 30,000 pounds per inch width of plate.

The spread of roller indicates no critical load.

Fig 17 a
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 92"
Test Mill



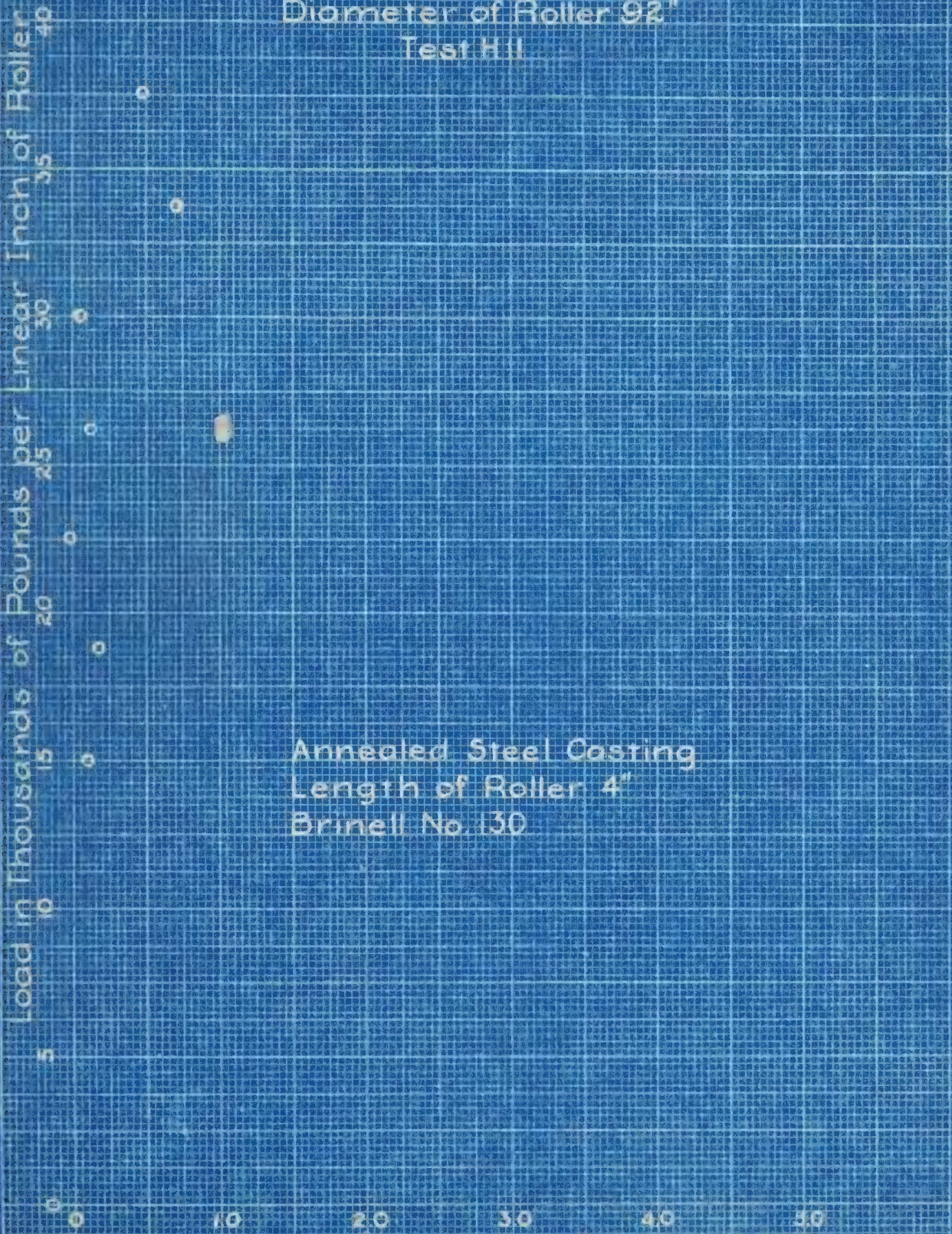
Illustrated Flow of Plate Data on Rolling Diameter of Roller 92 Test No.



Annealed Steel Casting
Thickness of Plate 12
Width of Plate 4
Brinell No. 130

Unit Longitudinal Flow in 1000 Strokes in 1 hour and 1 min

Fig. 7c
Spread of Roller
Due to Rolling
Diameter of Roller 92"
Test III



Annealed Steel Casting
Length of Roller 4"
Brinell No. 130

68 inch Roller on H12. The load deformation curves for this test are given in Fig. 18.

The critical load determined by lateral flow of plate is 22,100 pounds per inch width of plate.

The critical load determined by longitudinal flow of plate is 30,000 pounds per inch width of plate.

The spread of roller indicates no critical load.

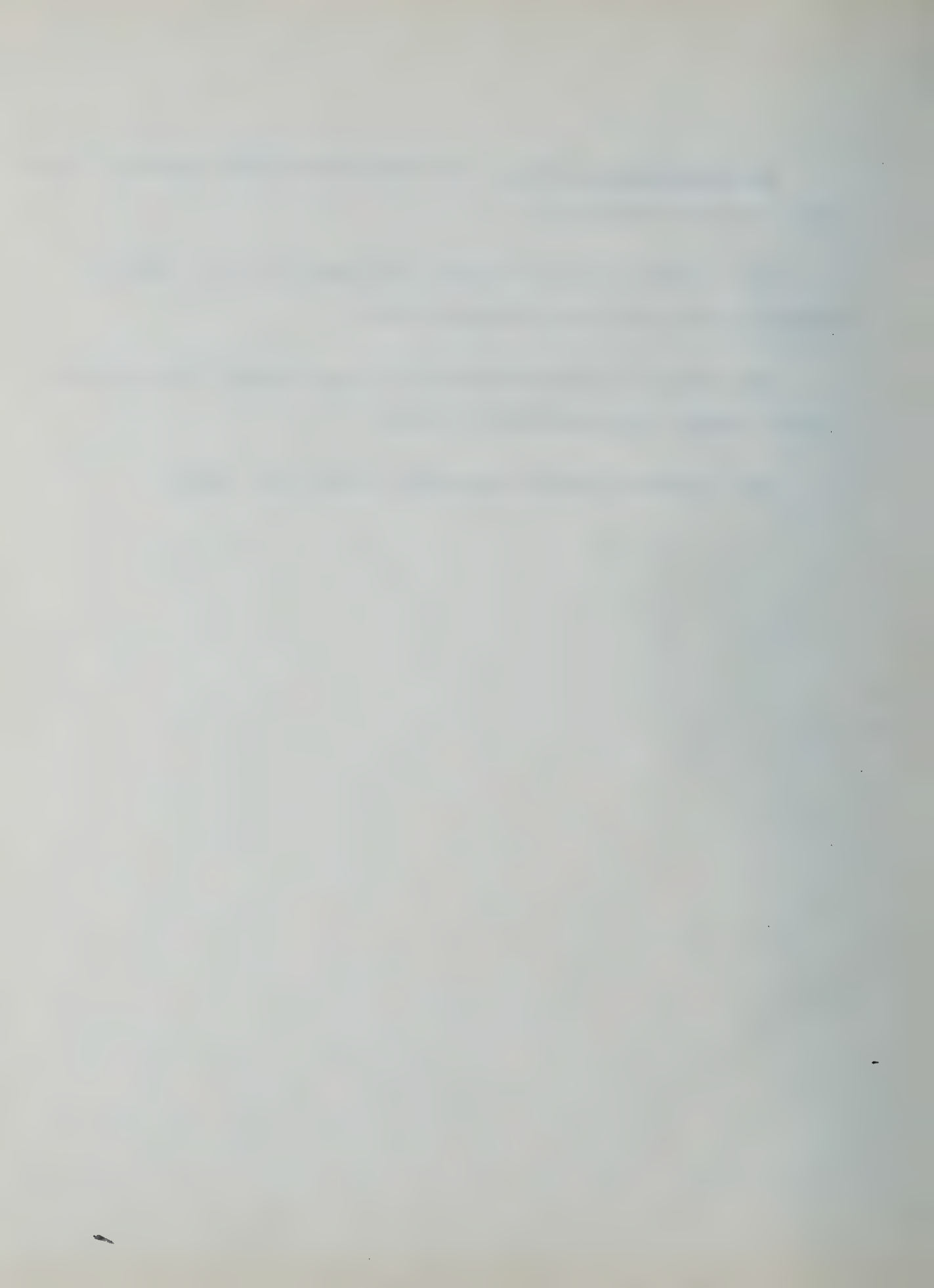


Fig. 1a
 Lateral Flow of Plate
 Due to Rolling
 Diameter of Roller 68"
 Test III2

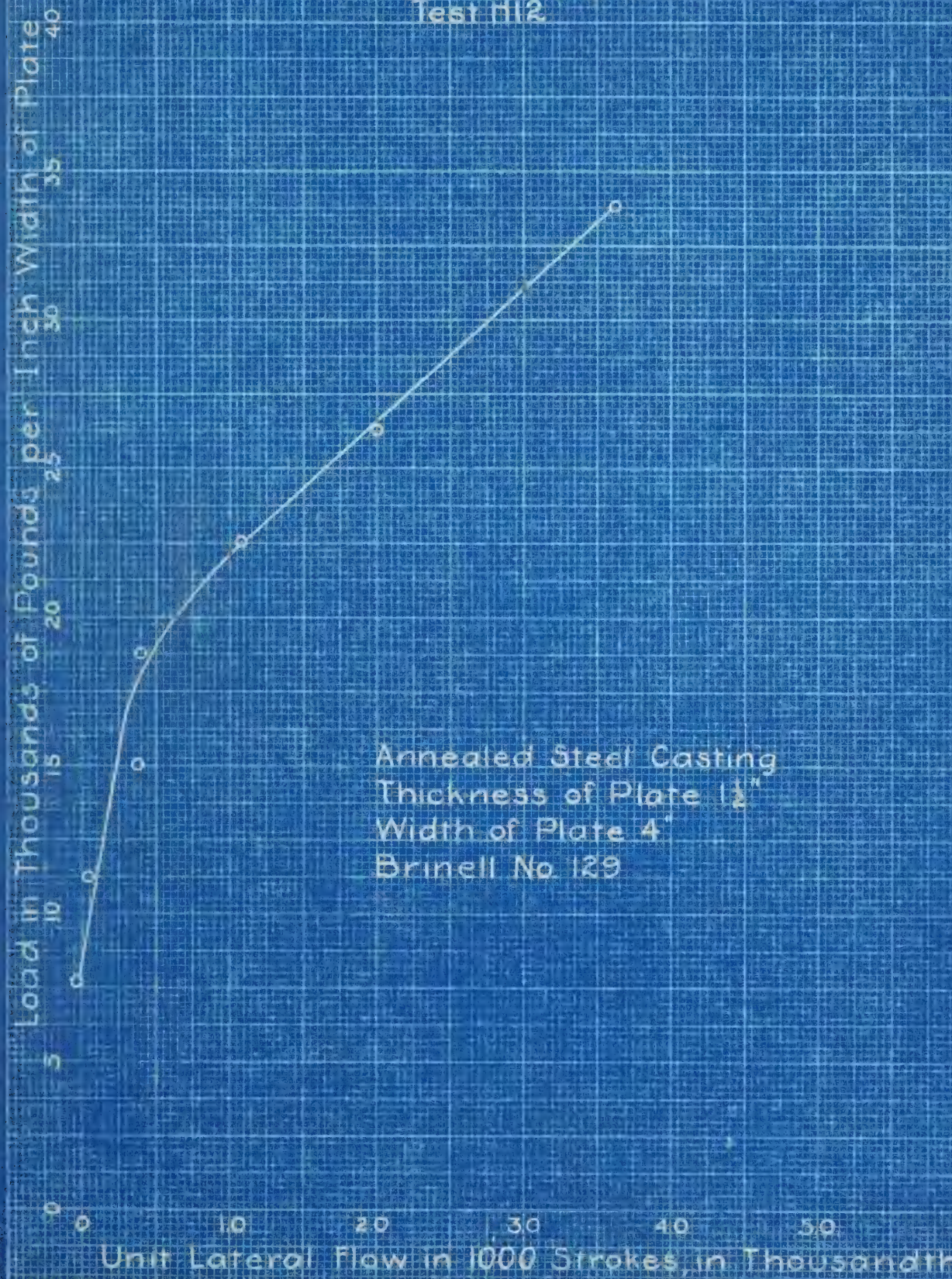


Fig 18b
Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 66"
Test H12

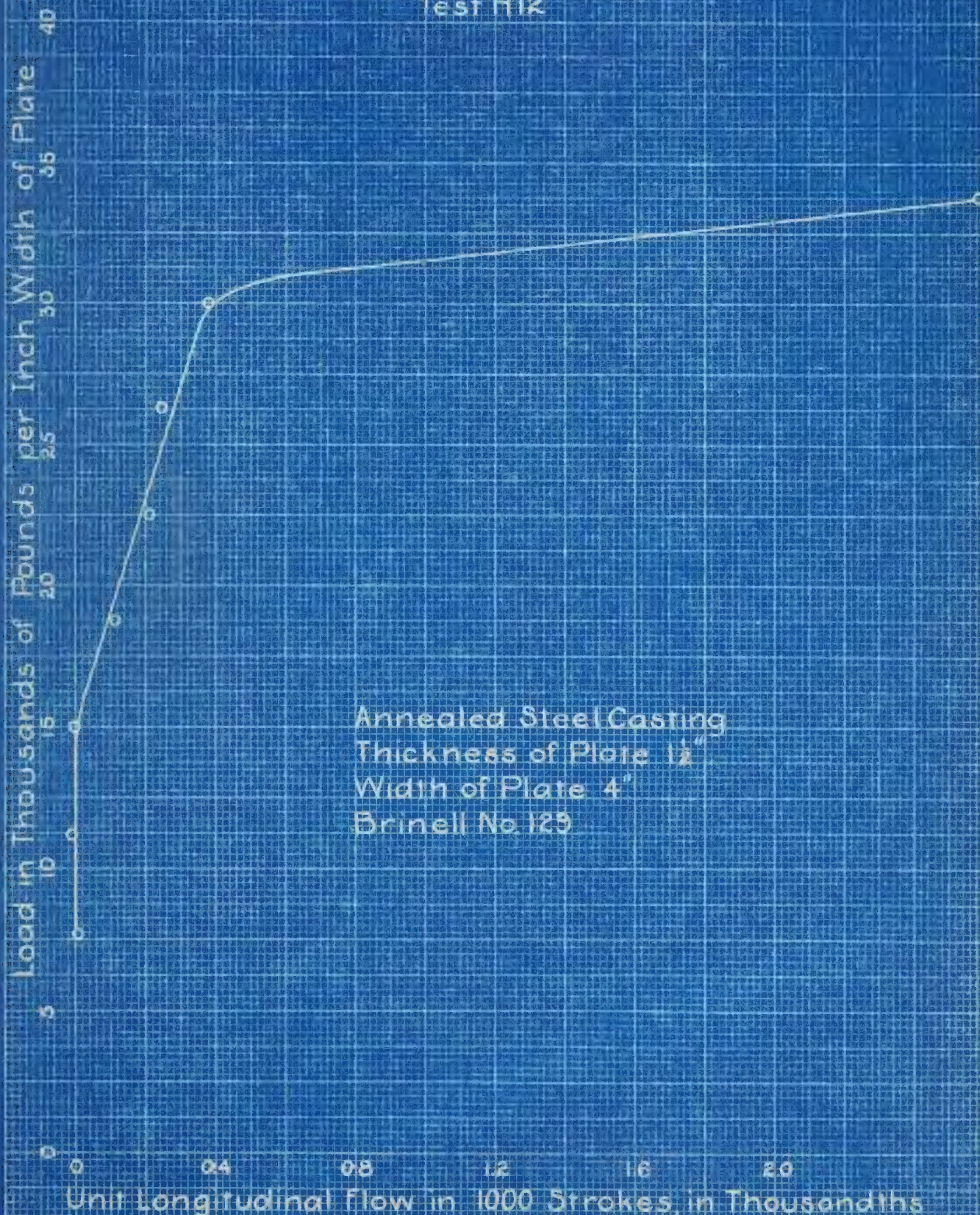


Fig. 18c
Spread of Roller
Due to Rolling
Diameter of Roller 68"
Test H12

Pounds per Linear Inch of Roller

40

35

30

25

20

15

10

5

0

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000

Fig. 18d
Spread of Roller
Due to Rolling
Diameter of Roller 68"
Test H12

40

35

30

25

20

15

10

5

0

0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290 300 310 320 330 340 350 360 370 380 390 400 410 420 430 440 450 460 470 480 490 500 510 520 530 540 550 560 570 580 590 600 610 620 630 640 650 660 670 680 690 700 710 720 730 740 750 760 770 780 790 800 810 820 830 840 850 860 870 880 890 900 910 920 930 940 950 960 970 980 990 1000

Fig. 18e
Spread of Roller in 1000 Strokes

36 inch Roller on H13. The load-deformation curves of this test are given in Fig. 19

The critical load determined by lateral flow of plate is 21,700 pounds per inch width of plate.

The critical load determined by longitudinal flow of plate is 19,800 pounds per inch width of plate.

The spread of roller indicates no critical load.

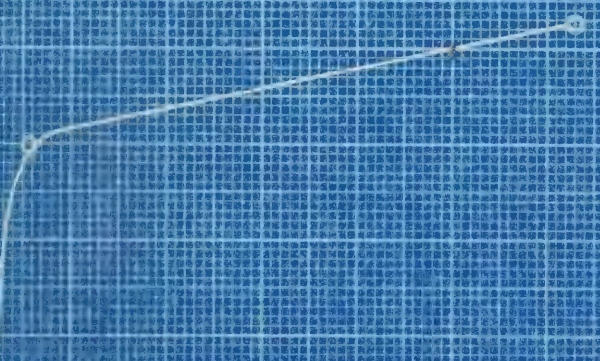


Umfeldwechsel als Folge von 1000 Störungen im Lebensrhythmus

Fig. 19b
Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 36"
Test No. 13

Load in Thousands of Pounds per Inch Width of Plate

20 15 10 5 0



Annealed Steel Casting
Thickness of Plate 1/2"
Width of Plate 4"
Drum No. 125

20

15

10

5

0

Unit Longitudinal Flow in 1000 Square Feet

Load in thousands of Pounds per Linear Inch of Roller

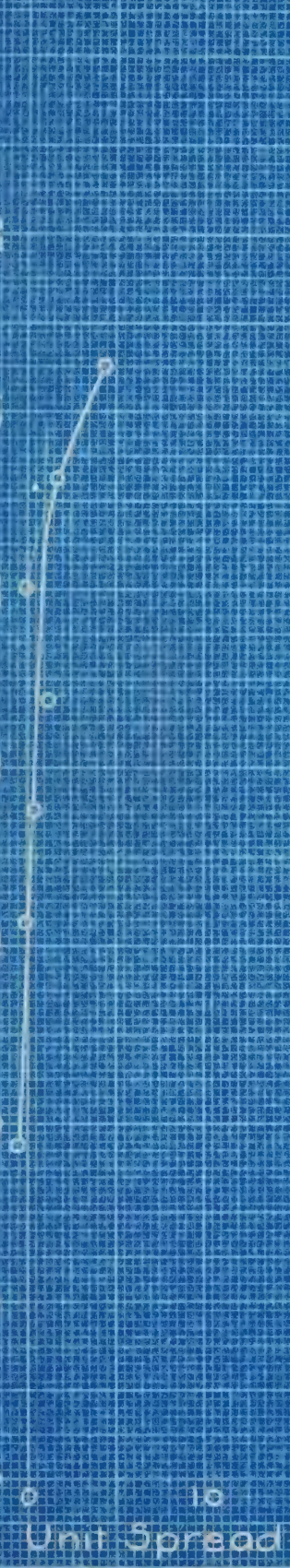


Fig. 15c
 Clearance of Roller
 Due to Rolling
 Diameter of Roller 66
 Feet 11.00

Annealed Steel Casting
 Length of Roller 4
 Brinell No. 125

Unit Speed of Roller in 1000 Strokes in 1000ths

23½ inch Roller on H1 and H2. This was the first test on small rollers. It appeared that two blocks could be rolled at the same time without much additional time or effort, one above and one below the roller. The idea was tried and great difficulty was encountered in maintaining even distribution of load on both blocks; so the method was abandoned. The top of the block is defined as the rolled surface although in H1 it was the lower face.

The load-deformation curves for this test are given in Fig. 30.

The critical load determined by lateral flow from the test on H1 is 21,800 pounds per inch width of plate and from the test on H2 is 21,800 pounds per inch width of plate.

The critical load determined by longitudinal flow is interpreted to be at the break in the curve. From the test on H1 it is 21,100 pounds per inch width of plate and from the test on H2 it is 22,000 pounds per inch width of plate.

The critical load determined by the spread of roller from the test on H1 is 23,500 pounds per linear inch of roller and from the test on H2 is 21,800 pounds per linear inch of roller.

Weight in Pounds of Plate per Inch Width of Plate

25
20
15
10
5
0

0 10 20 30 40 50

Unit Lateral Flow in 1000 Strokes in Thousandths

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

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0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

Unit Lateral Flow in 1000 Strokes in Thousandths

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

0 10 20 30 40 50

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0 10 20 30 40 50

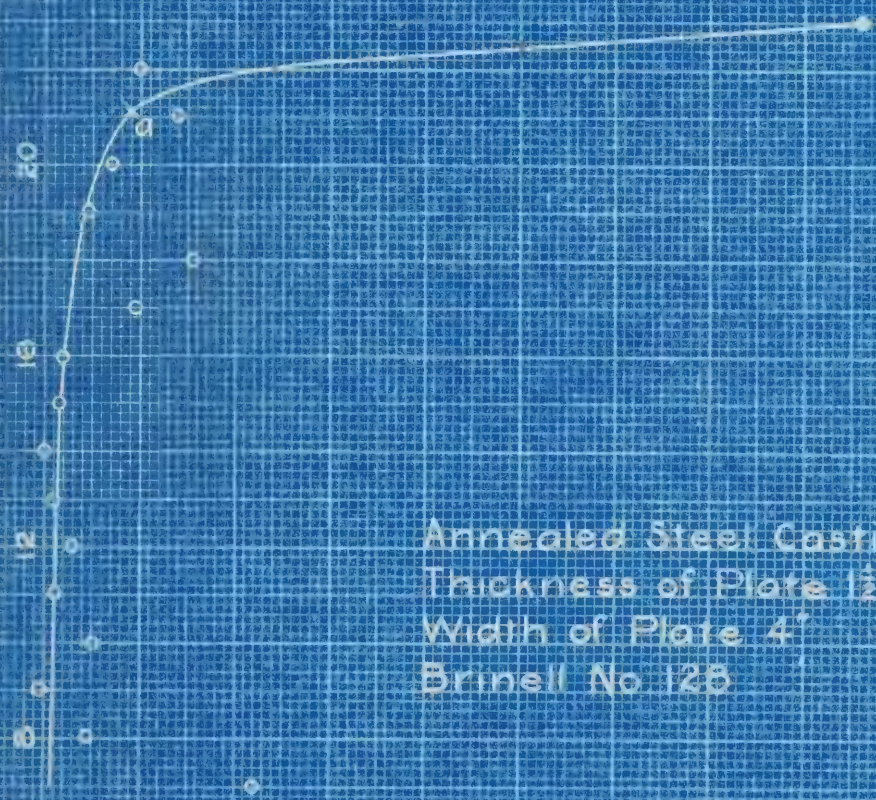
0 10 20 30 40 50

Annexed Steel Casting
Thickness of Plate 1/2"
Width of Plate 4"
Brinell No. 28

Fig. 20b
Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 23½"
Test No. 11

Scale in Thousands of Pounds per Inch Width of Plate

24
20
16
12
8
4
0



Annealed Steel Casting
Thickness of Plate 12
Width of Plate 4
Brinell No. 726

0.0

0.4

0.8

1.2

1.6

2.0

Unit Longitudinal Flow in 1000 Strokes in Thousandths

Fig 208
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 232"
Test H2

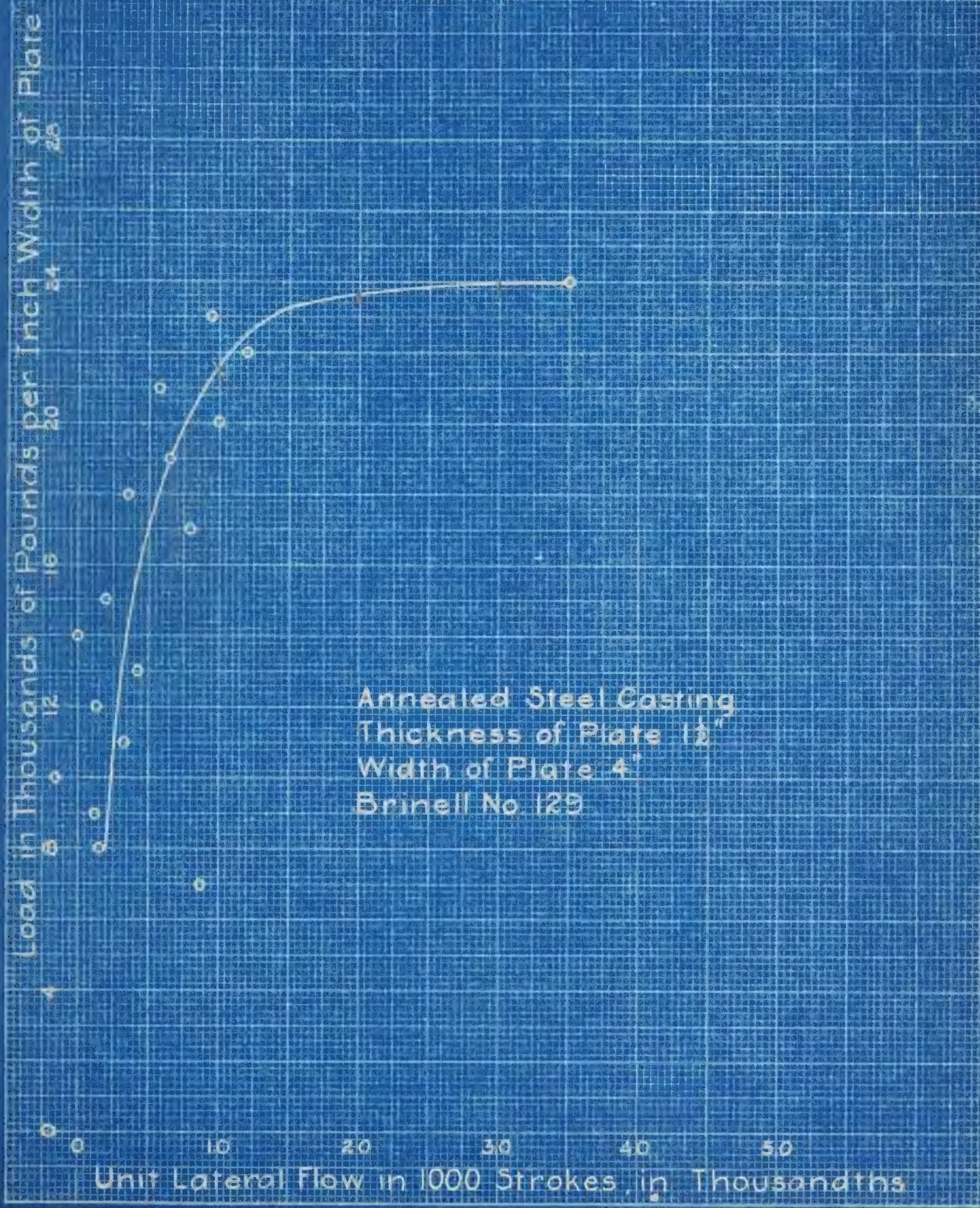
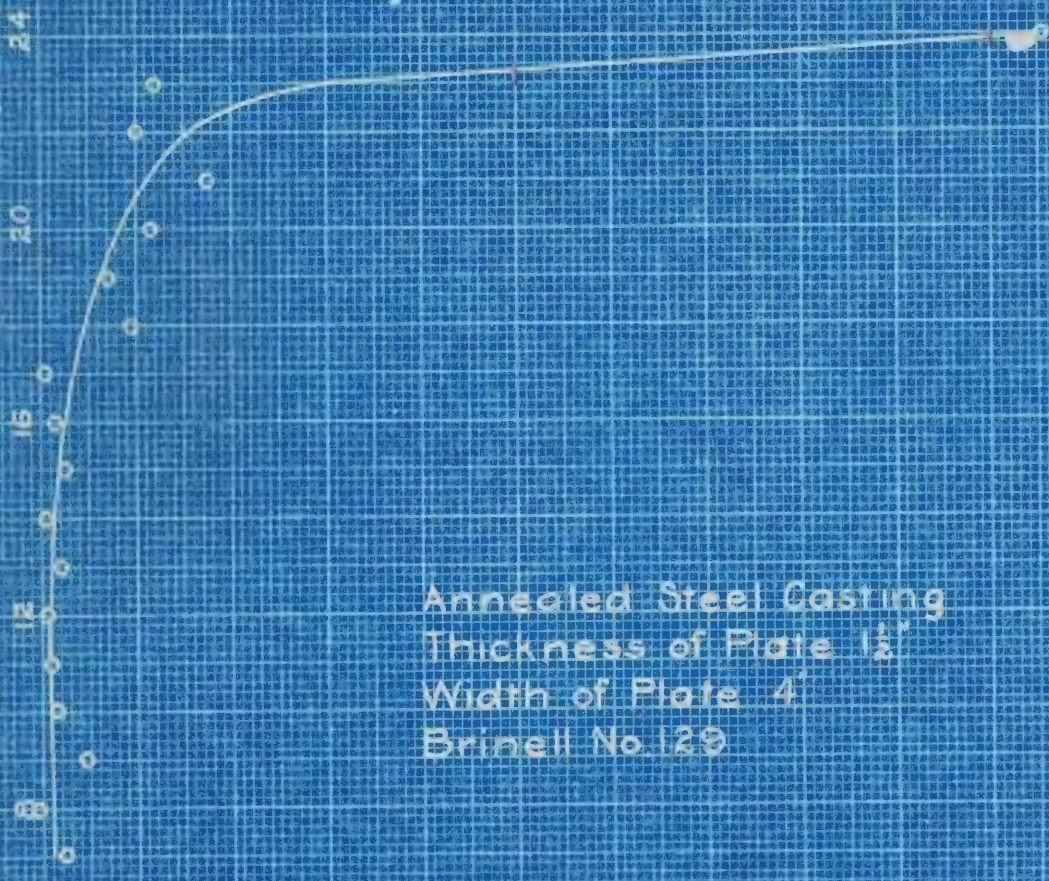


Fig. 20
Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 235"
Test #12

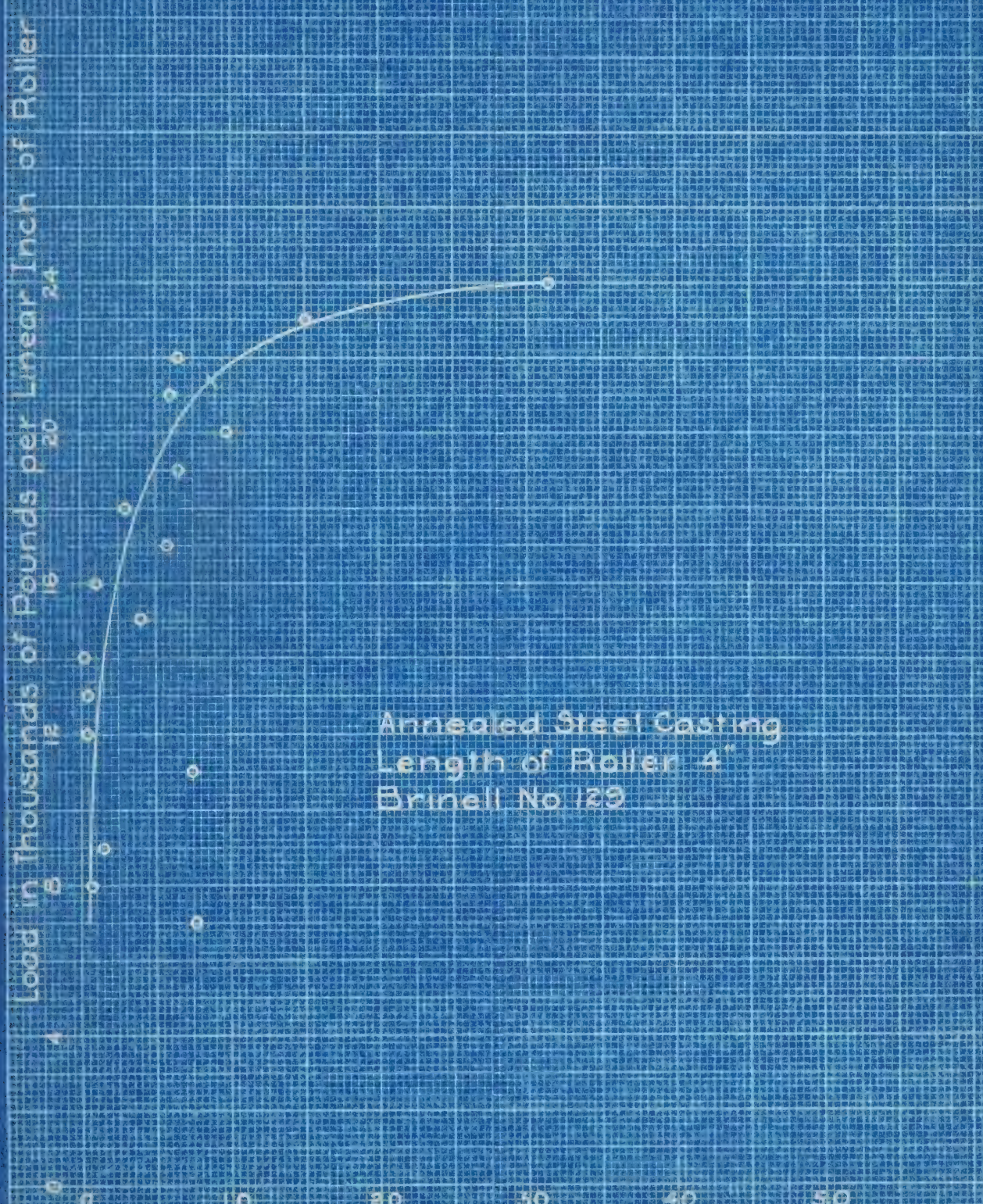
Circle in Thousands of Pounds per Inch Width of Plate



Annealed Steel Casting
Thickness of Plate 12
Width of Plate 4
Brinell No. 29

0 0.4 0.8 1.2 1.6 2.0
Unit Longitudinal Flow in 1000 Strokes in Thousandths

Fig. 201
Spread of Roller
Due to Rolling
Diameter of Roller, 2 1/2"
Test H12



Unit Spread of Roller in 1000 lb. per in. of roller length

16" Roller on H5. The excessive deformation in the roller at the first loads may have been due to loose micrometer points. They were removed into the roller after the second increment.

The load-deformation curves of this test are given in Fig. 31.

The critical load determined from the lateral flow is 15,200 pounds per inch width of plate and from the spread of roller it is 14,800 pounds per linear inch of roller.

The critical load determined from the longitudinal flow is interpreted to be that load at the reversal of curvature and is 13,300 pounds per inch width of plate.

Fig. 21a
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 16"
Test H5

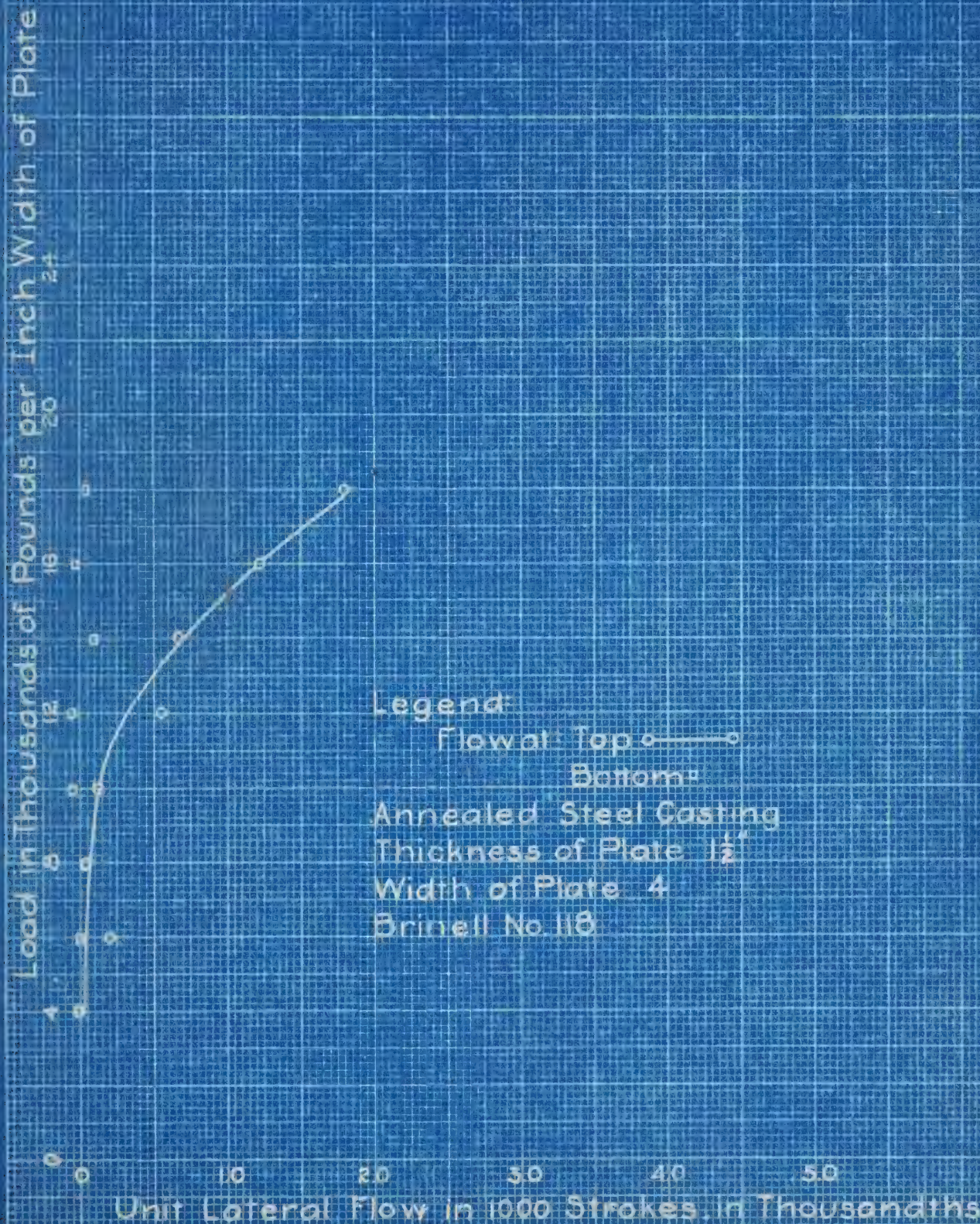
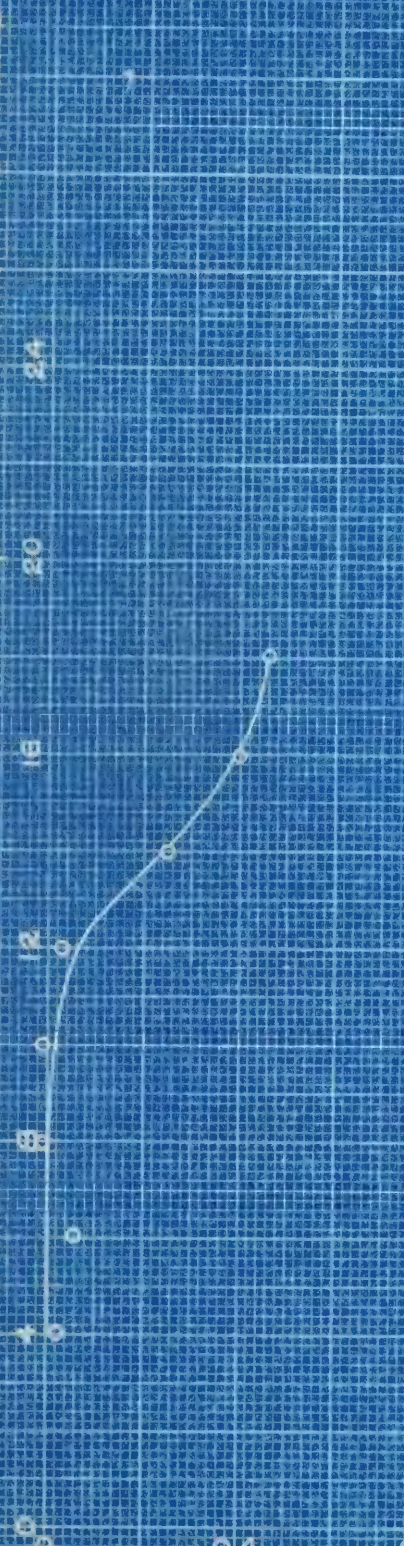


Fig. 216 Longitudinal Flow of Plate Due to Rolling Diameter of Roller, 16" Test No. 5

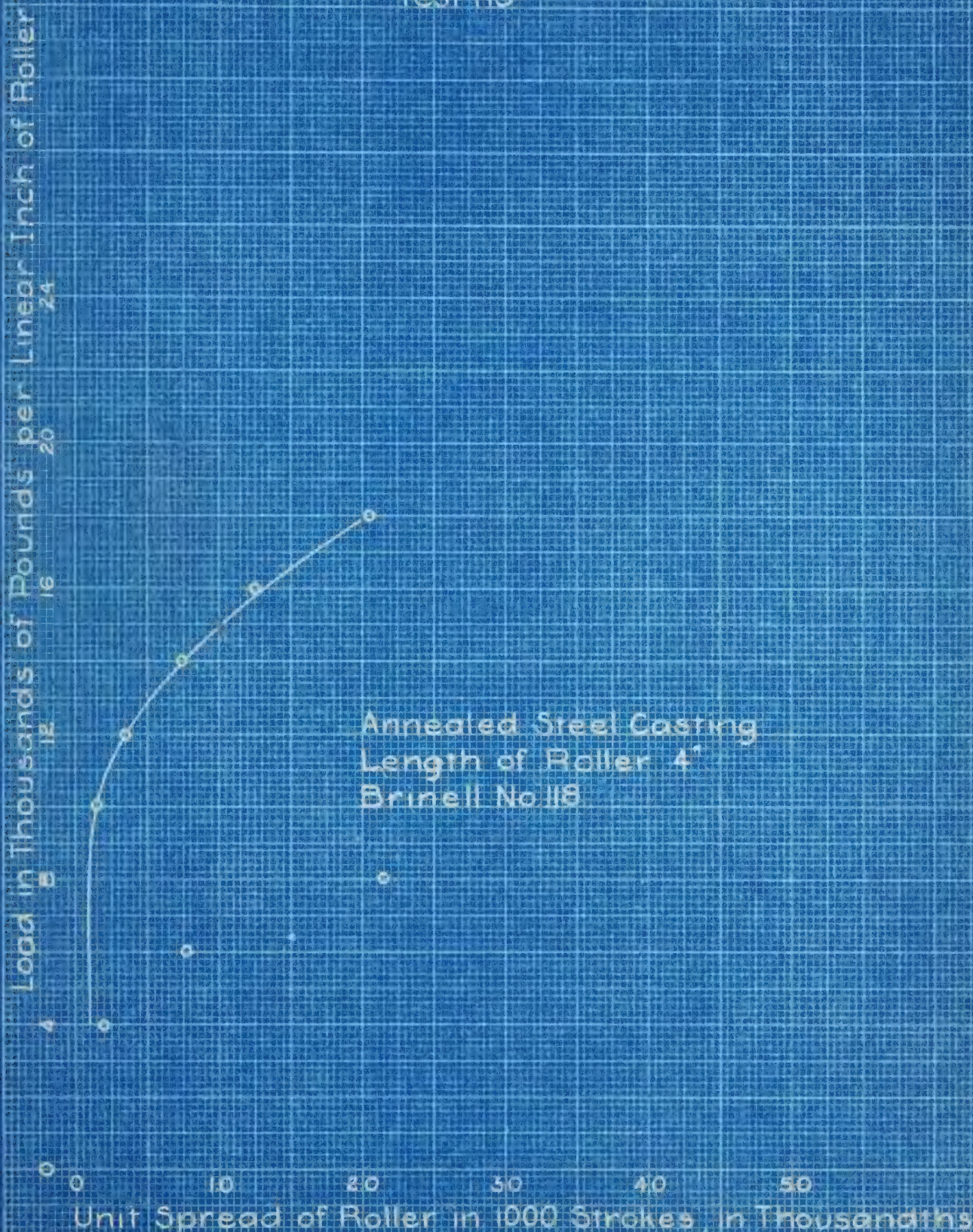
Speed in Thousands of Revolutions per Minute



Annealed Steel Casing
Thickness of Plate, 2"
Width of Plate, 4"
Brinell No. 16

Unit Longitudinal Flow in 1000 Strokes per Minute

Fig. 21c
Spread of Roller
Due to Rolling
Diameter of Roller 16"
Test #5



12 Inch Roller on H3. The load-deformation curves of this test are given in Figure 22.

The critical load determined from the lateral flow is 14,500 pounds per inch width of plate and from the spread of roller it is only 8200 pounds per linear inch of roller. The writer has no explanation for the great difference.

The critical load determined by longitudinal flow is interpreted to be at the point of reversal of curvature and is 15,700 pounds per inch width of plate.

The high value of the Brinell number may be due to the fact that the hardness test was not made until the inverted block had been tested under the 10 inch roller.

Fig 22a
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 12"
Testy H13

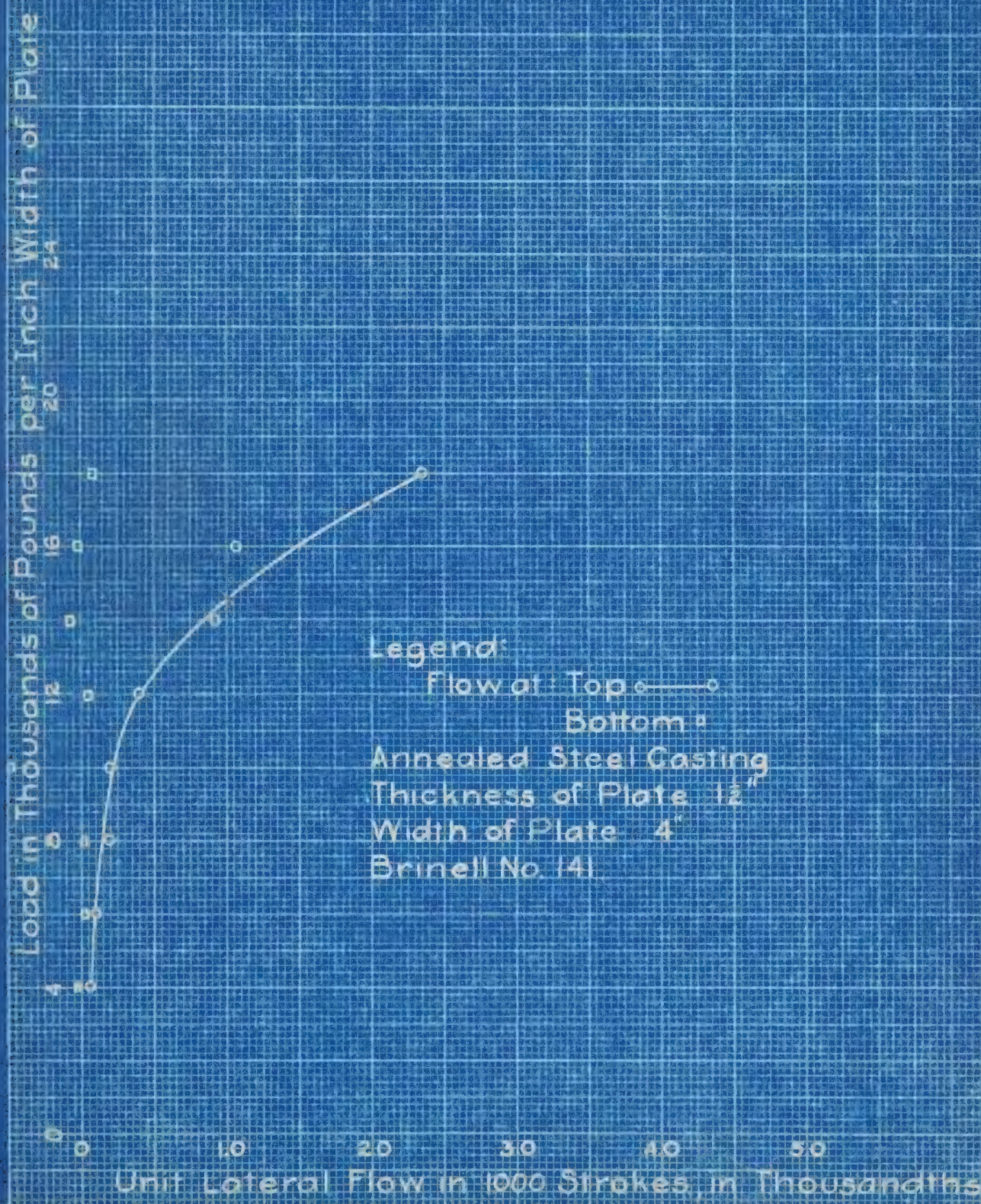
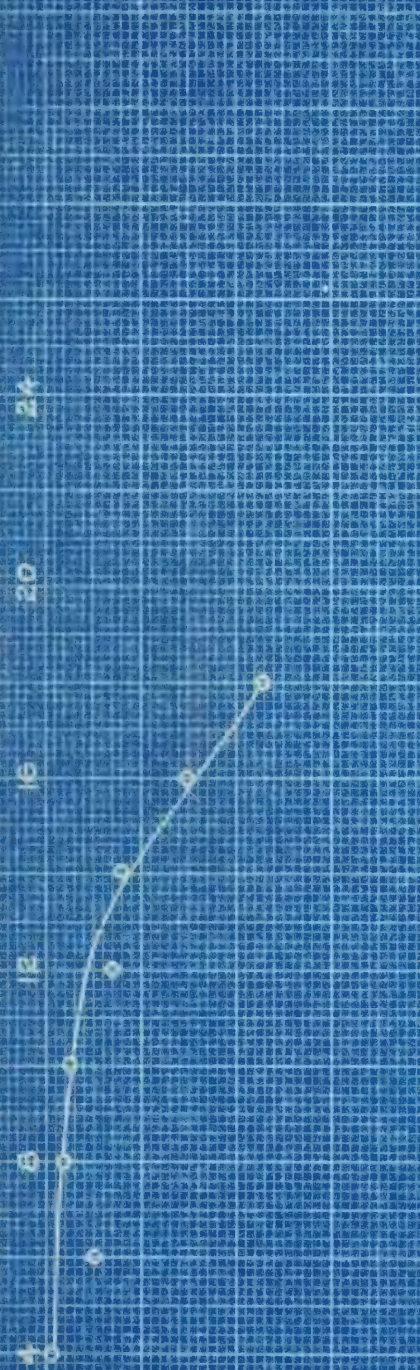


Fig. 226
 Longitudinal Flow of Plate
 Due to Rolling
 Diameter of Roller 12"
 Test #13

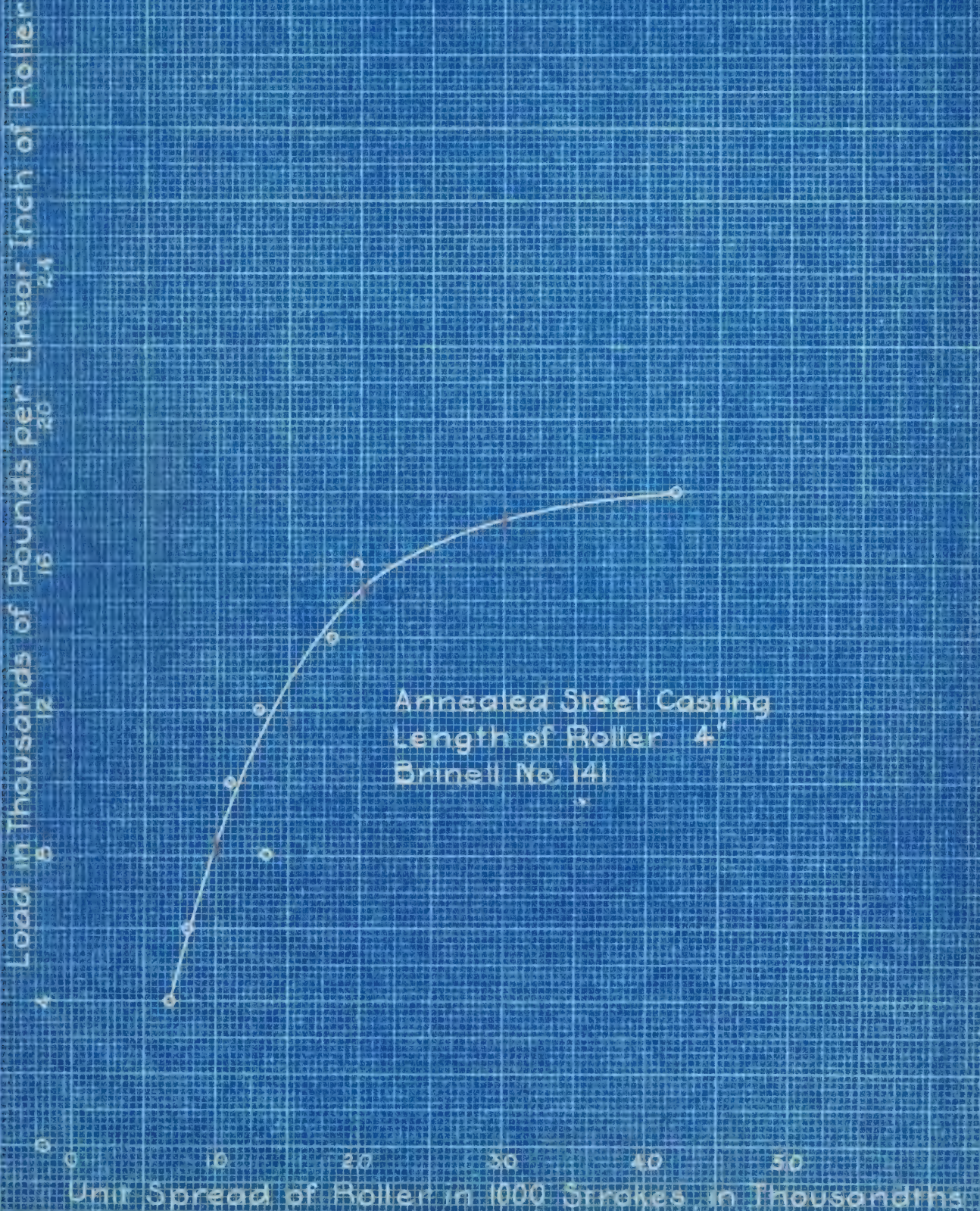
Plate Thickness of Plates set from 16 to 20



Annealed Steel Conting
 Thickness of Plate 12"
 Width of Plate 4"
 Brinell No. 41

Unit Longitudinal Flow in 1000 Strokes in Thousandths

Fig. 22c
Spread of Roller
Due to Rolling
Diameter of Roller 12"
Test H3



10 Inch Roller on H3A. The load-deformation curves of this test are given in Fig. 23.

The critical load determined from the lateral flow is 10,100 pounds per inch width of plate and from the spread of roller it is 11,400 pounds per linear inch of roller.

The critical load determined by longitudinal flow is interpreted to be at the point of reversal of curvature and is 12,000 pounds per inch width of plate.

Fig. 23a
 Lateral Flow of Plate
 Due to Rolling
 Diameter of Roller 10"
 Test H3A

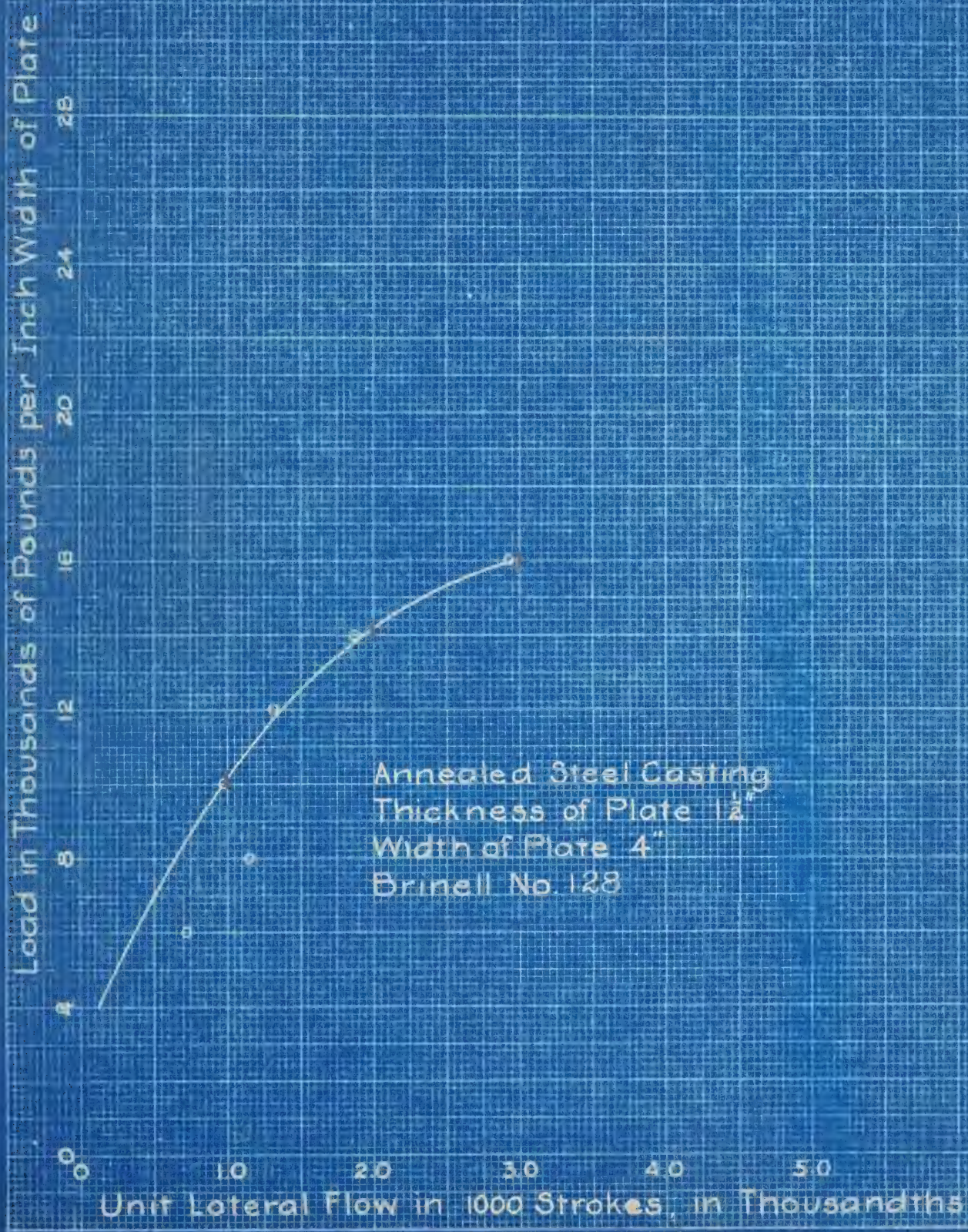
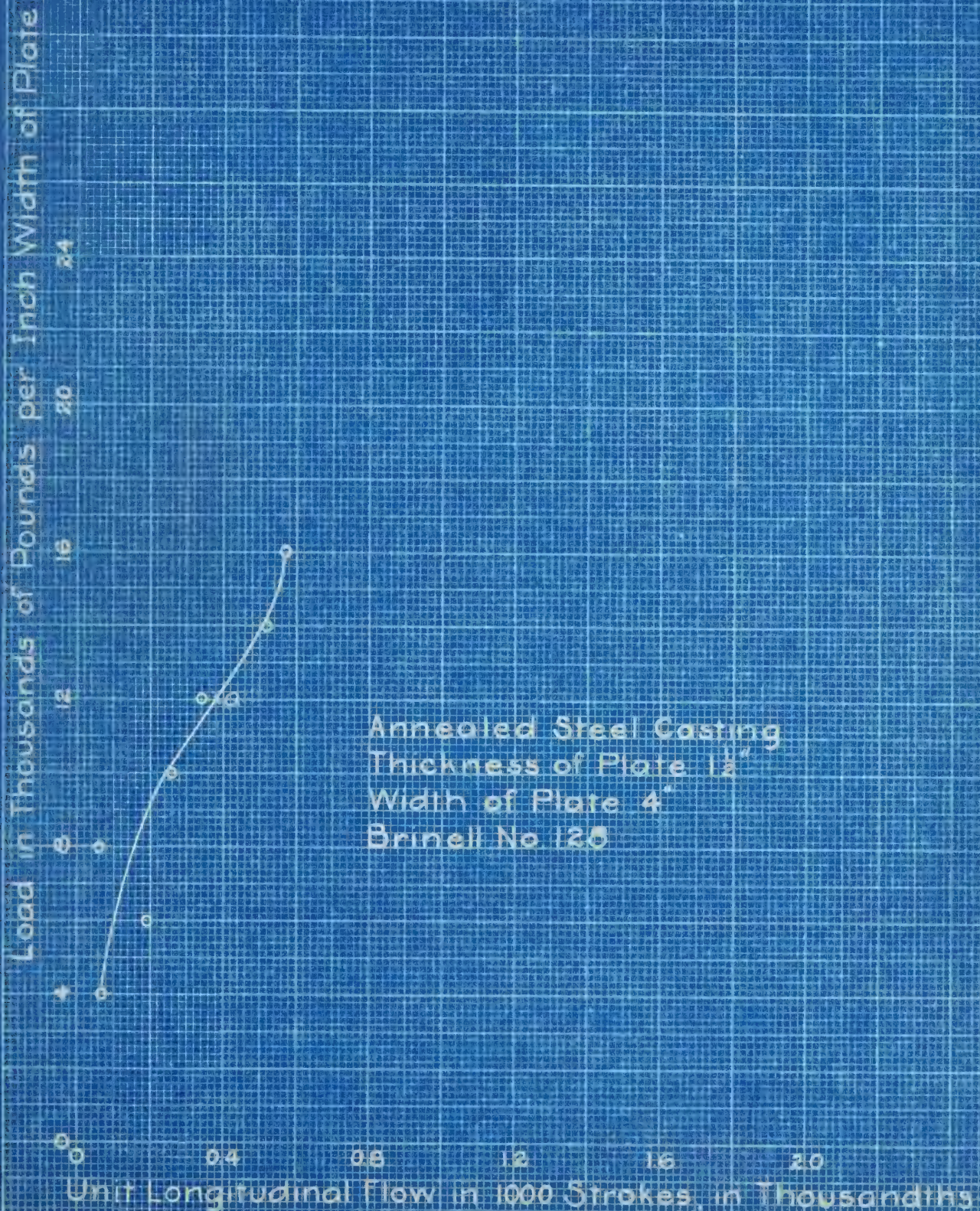


Fig 23b
Longitudinal flow of Plate
Due to Rolling
Diameter of Roller 10"
Test H3A



8 Inch Roller on H5. The load deformation curves of this test are given in Fig. 24.

The critical load determined from the lateral flow is 10,800 pounds per inch width of plate and from the spread of roller it is 11,900 pounds per linear inch of roller.

The curve of longitudinal flow indicates neither a reversal of curvature nor break.

Fig. 240
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 8"
Test No. A

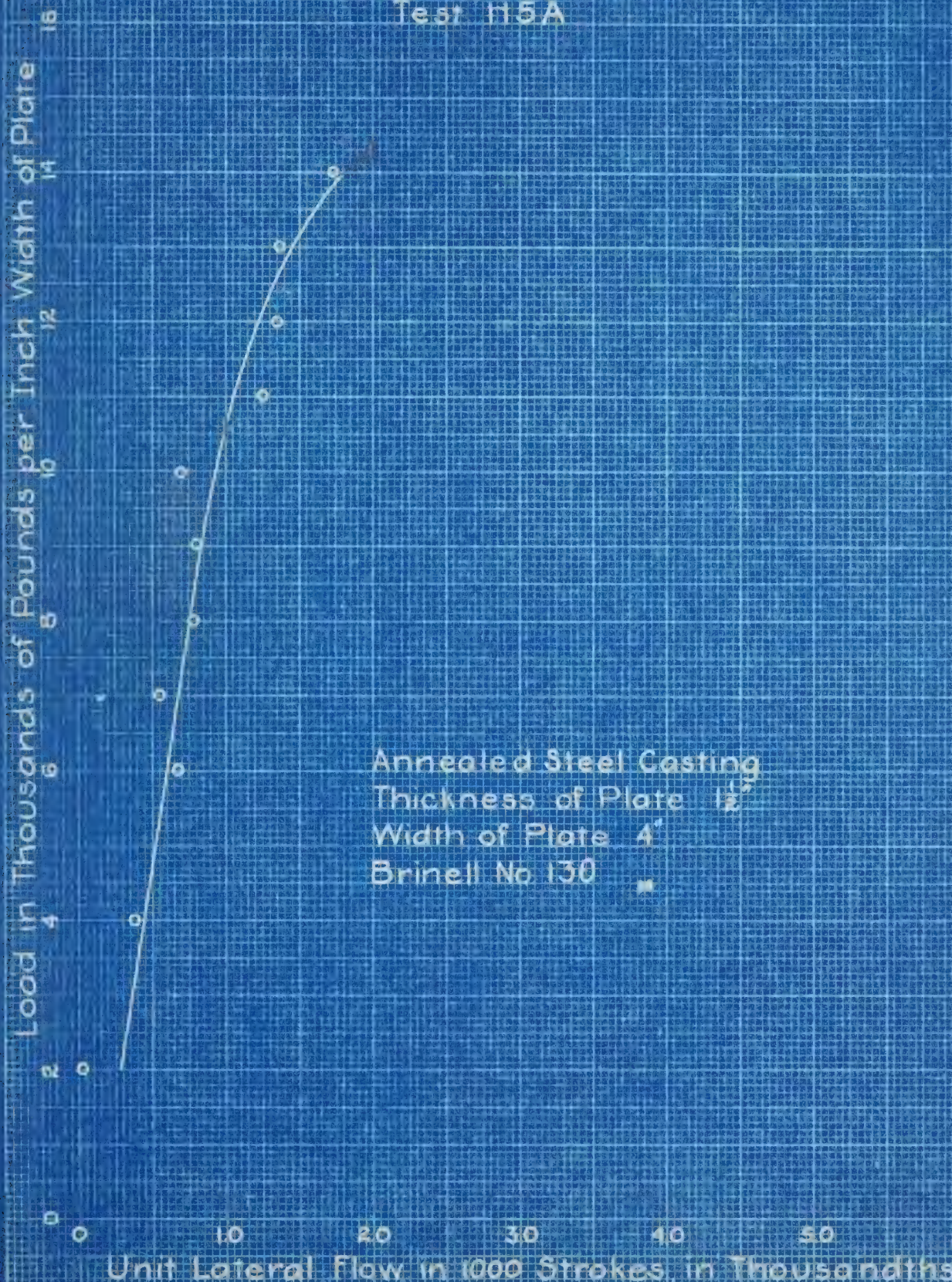
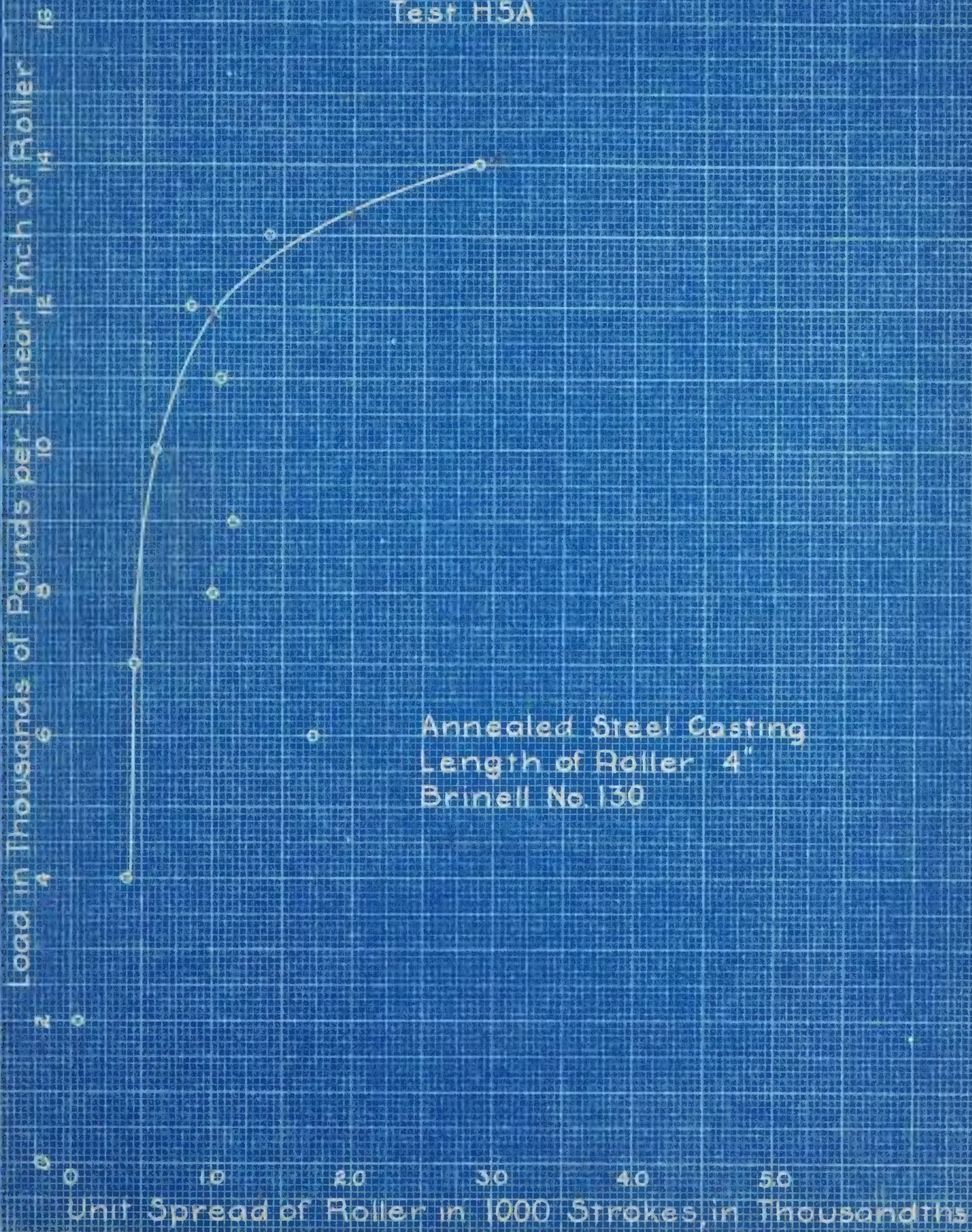


Fig 24c
 Spread of Roller
 Due to Rolling
 Diameter of Roller 8"
 Test H5A



Annealed Steel Casting
 Length of Roller 4"
 Brinell No. 130

6 Inch Roller on H9. The load-deformation curves of this test are given in Fig. 25.

The critical load determined from the internal flow is 9,500 pounds per inch width of plate. No interpretation was made from the data for spread of roller.

The curve of longitudinal flow indicates neither a reversal of curvature nor a break.

一、**“三化”**：即“**工业化、城镇化、信息化**”。
 二、**“三基”**：即“**基层、基础、基本功**”。
 三、**“三抓”**：即“**抓班子、抓队伍、抓作风**”。
 四、**“三强”**：即“**强素质、强能力、强作风**”。
 五、**“三好”**：即“**好班子、好队伍、好作风**”。
 六、**“三优”**：即“**优环境、优服务、优效率**”。
 七、**“三满意”**：即“**群众满意、企业满意、社会满意**”。
 八、**“三到位”**：即“**领导到位、责任到位、措施到位**”。
 九、**“三落实”**：即“**责任落实、措施落实、资金落实**”。
 十、**“三公开”**：即“**公开决策、公开执行、公开结果**”。
 十一、**“三监督”**：即“**党内监督、民主监督、社会监督**”。
 十二、**“三保障”**：即“**保障权益、保障安全、保障稳定**”。
 十三、**“三促进”**：即“**促进发展、促进和谐、促进稳定**”。
 十四、**“三提高”**：即“**提高素质、提高能力、提高水平**”。
 十五、**“三增强”**：即“**增强信心、增强动力、增强决心**”。
 十六、**“三坚持”**：即“**坚持原则、坚持真理、坚持正义**”。
 十七、**“三做到”**：即“**做到忠诚、做到干净、做到担当**”。
 十八、**“三必须”**：即“**必须对党忠诚、必须清正廉洁、必须敢于担当**”。
 十九、**“三不能”**：即“**不能搞特权、不能搞特殊、不能搞例外**”。
 二十、**“三反对”**：即“**反对形式主义、反对官僚主义、反对享乐主义**”。
 二十一、**“三杜绝”**：即“**杜绝腐败现象、杜绝违法乱纪、杜绝损害群众利益**”。
 二十二、**“三实现”**：即“**实现科学发展、实现社会和谐、实现人民幸福**”。
 二十三、**“三建设”**：即“**建设生态文明、建设文化强国、建设美丽中国**”。
 二十四、**“三推进”**：即“**推进依法治国、推进全面深化改革、推进全面从严治党**”。
 二十五、**“三落实”**：即“**落实主体责任、落实监督责任、落实问责责任**”。
 二十六、**“三强化”**：即“**强化纪律约束、强化制度执行、强化监督检查**”。
 二十七、**“三提升”**：即“**提升党性修养、提升道德境界、提升履职能力**”。
 二十八、**“三增强”**：即“**增强政治定力、增强思想定力、增强道德定力**”。
 二十九、**“三做到”**：即“**做到不忘初心、做到牢记使命、做到知行合一**”。
 三十、**“三坚持”**：即“**坚持实事求是、坚持群众路线、坚持艰苦奋斗**”。
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 五十九、**“三强化”**：即“**强化纪律约束、强化制度执行、强化监督检查**”。
 六十、**“三提升”**：即“**提升党性修养、提升道德境界、提升履职能力**”。
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 七十、**“三强化”**：即“**强化纪律约束、强化制度执行、强化监督检查**”。
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 七十二、**“三增强”**：即“**增强政治定力、增强思想定力、增强道德定力**”。
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 八十五、**“三坚持”**：即“**坚持实事求是、坚持群众路线、坚持艰苦奋斗**”。
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 一百、**“三建设”**：即“**建设法治中国、建设文化强国、建设美丽中国**”。
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 一百零三、**“三强化”**：即“**强化纪律约束、强化制度执行、强化监督检查**”。
 一百零四、**“三提升”**：即“**提升党性修养、提升道德境界、提升履职能力**”。
 一百零五、**“三增强”**：即“**增强政治定力、增强思想定力、增强道德定力**”。
 一百零六、**“三做到”**：即“**做到不忘初心、做到牢记使命、做到知行合一**”。
 一百零七、**“三坚持”**：即“**坚持实事求是、坚持群众路线、坚持艰苦奋斗**”。

[illegible]

Amber Lee Stetson The Artist of Plots With Volume 4 of the Siren Song

10 20 30 40 50
Low flow in 1000 cfs or less

Fig. 251a
Longitudinal Flow of Plate
Due to Rolling
Diameter of Roller 6"
Test No. 9

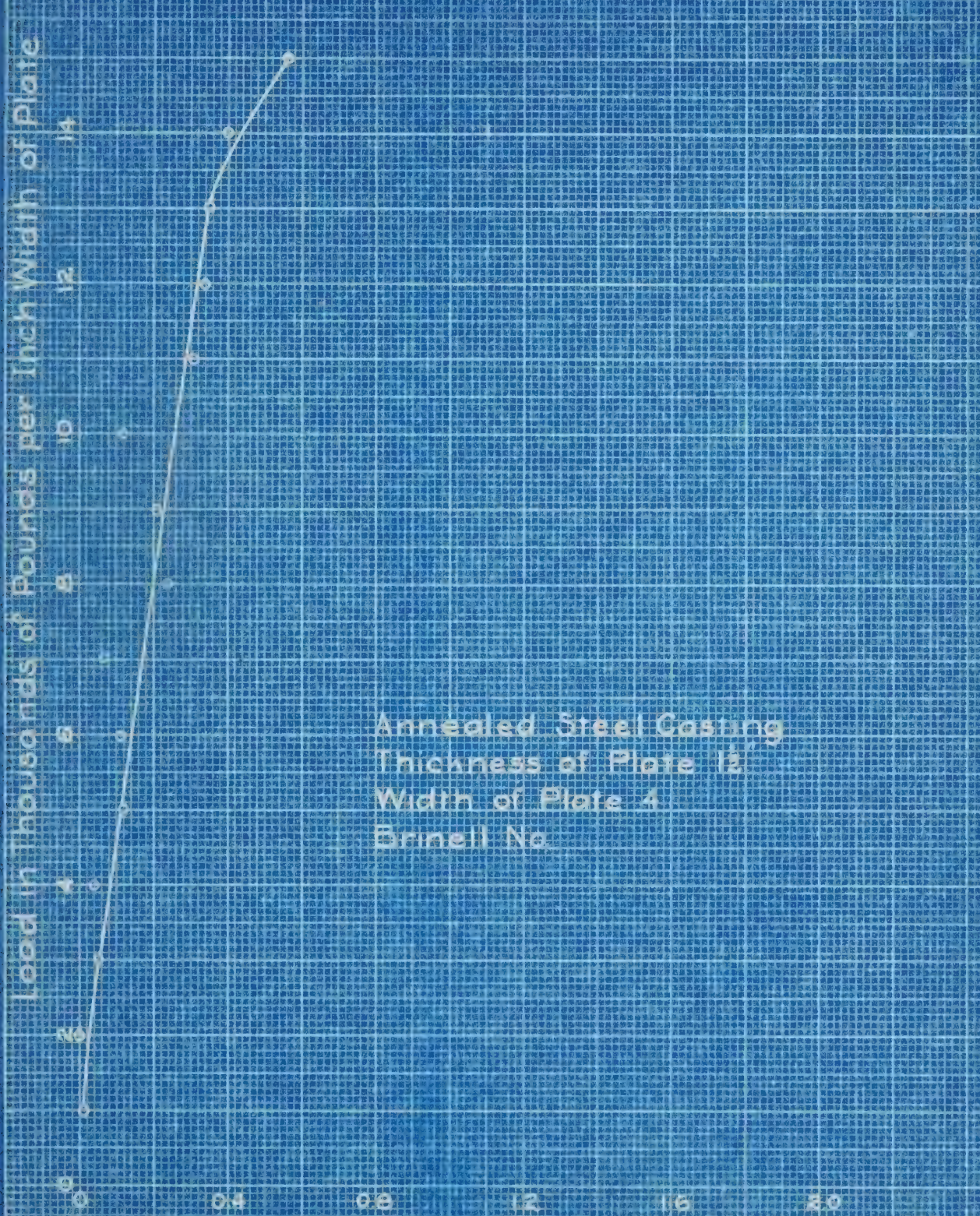


Fig. 251b
Annular Steel Circle
Thickness of Plate 1/4"
Width of Plate 4"
Roller No. 1

Fig. 251c
Longitudinal Flow in 1000 Cycles

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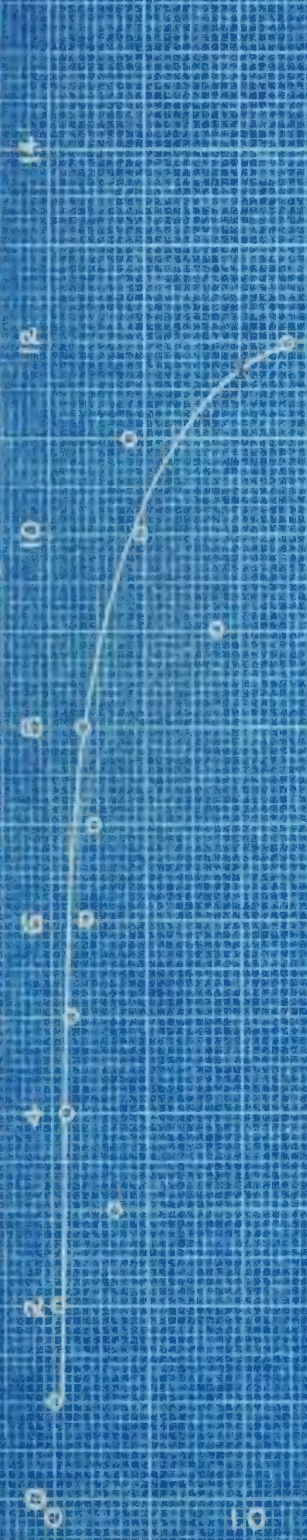
4 Inch Roller on H7. The load-deformation curves of this test are given in Fig. 26.

The critical load determined from the lateral flow of plate is 11,700 pounds per inch width of plate and from the spread of roller it is 11,000 pounds per linear inch of roller.

The curve of longitudinal flow indicates neither a break nor a reversal of curvature.

The 26d
Lateral Flow of Plate
Due to Rolling
Diameter of Roller 4
Test # 7

Load in Thousands of Pounds per Inch Width of Plate



Annealed Steel Casting
Thickness of Plate 12
Width of Plate 4
Brinell No. 128

Unit Lateral Flex in 1000 Strokes in Thousands of Pounds

Fig. 26b
 Longitudinal Flow of Plate
 Due to Rolling
 Diameter of Roller 4"
 Test H7

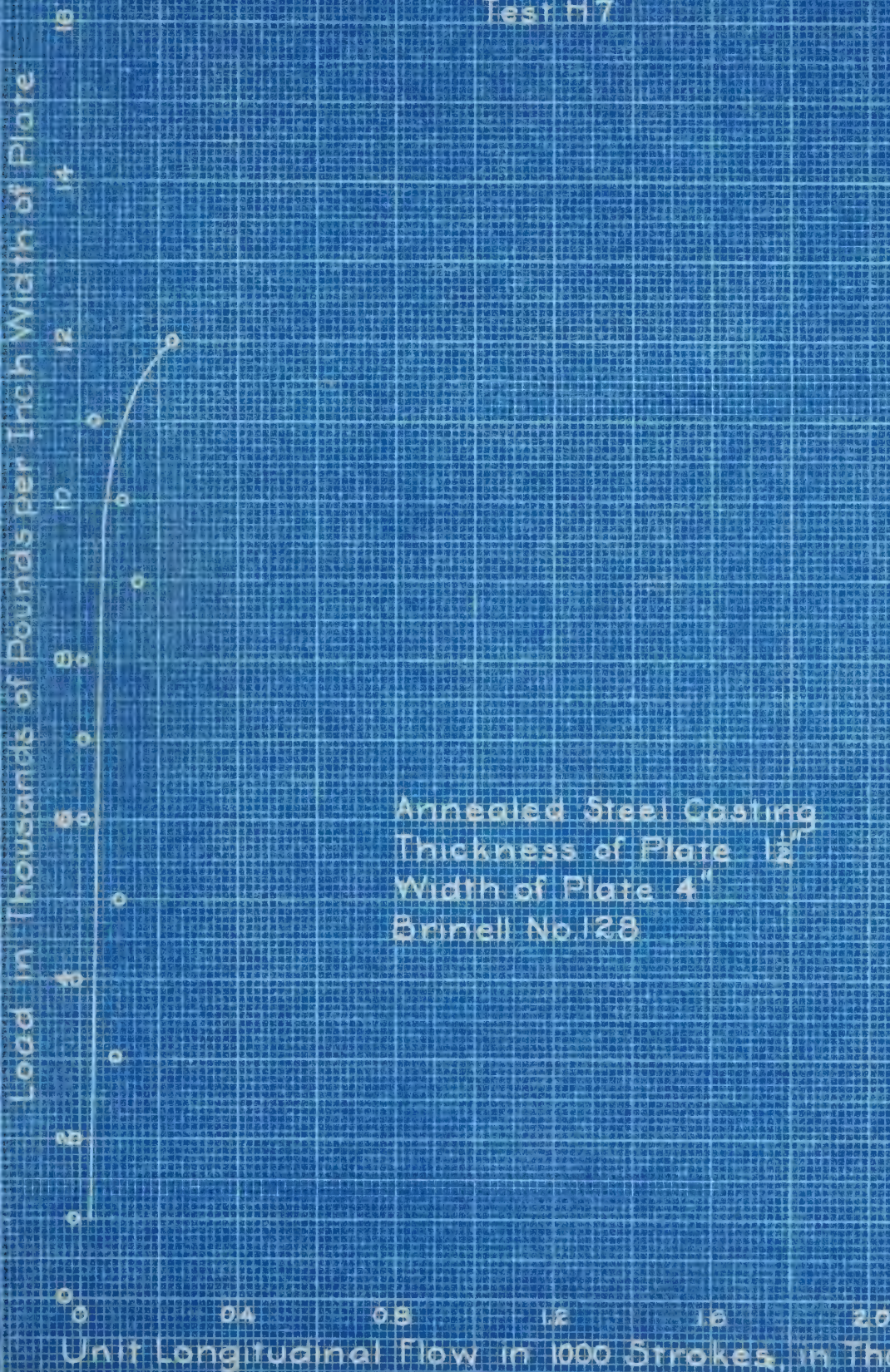
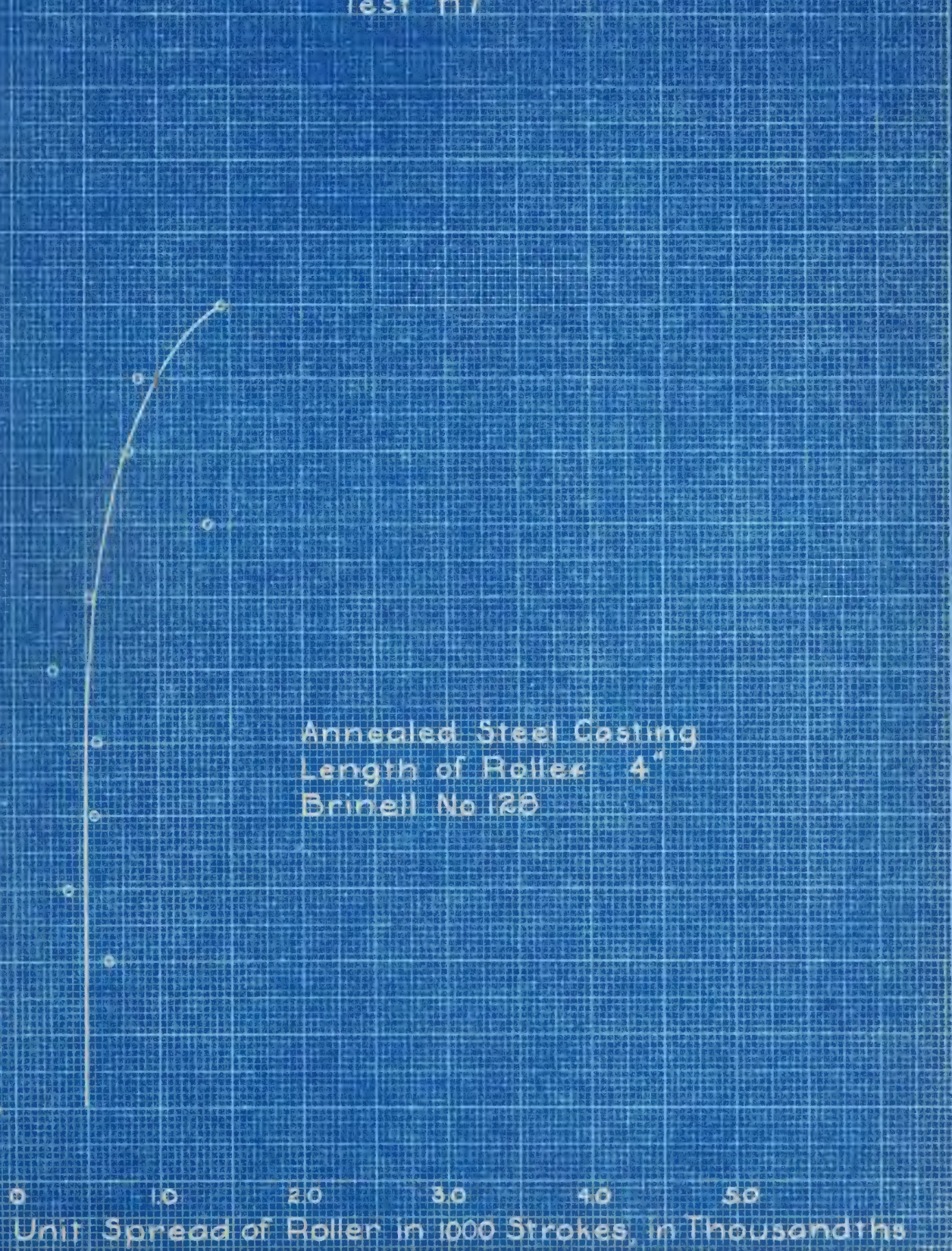


Fig 26c
 Spread of Roller
 Due to Rolling
 Diameter of Roller 4"
 Test H7

Load in Thousands of Pounds per Linear Inch of Roller



2 Inch Roller on HTA. It was impossible to measure the spread of roller in this test because the ends of the specimen rubbed on the guides in the lower side of the carriage. It was thought that the carriage might slide instead of roll on the specimen after the plate suffered some deformation; so it was watched carefully and did not slide.

The load-deformation curves of this test are given in Fig. 37.

Critical load determined from the lateral flow is 10,100 pounds per inch width of plate.

The longitudinal flow indicates neither a break nor a reversal of curvature.

Fig. 27a
 Lateral Flow of Plate
 Due to Rolling
 Diameter of Roller 2"
 Test H-7A

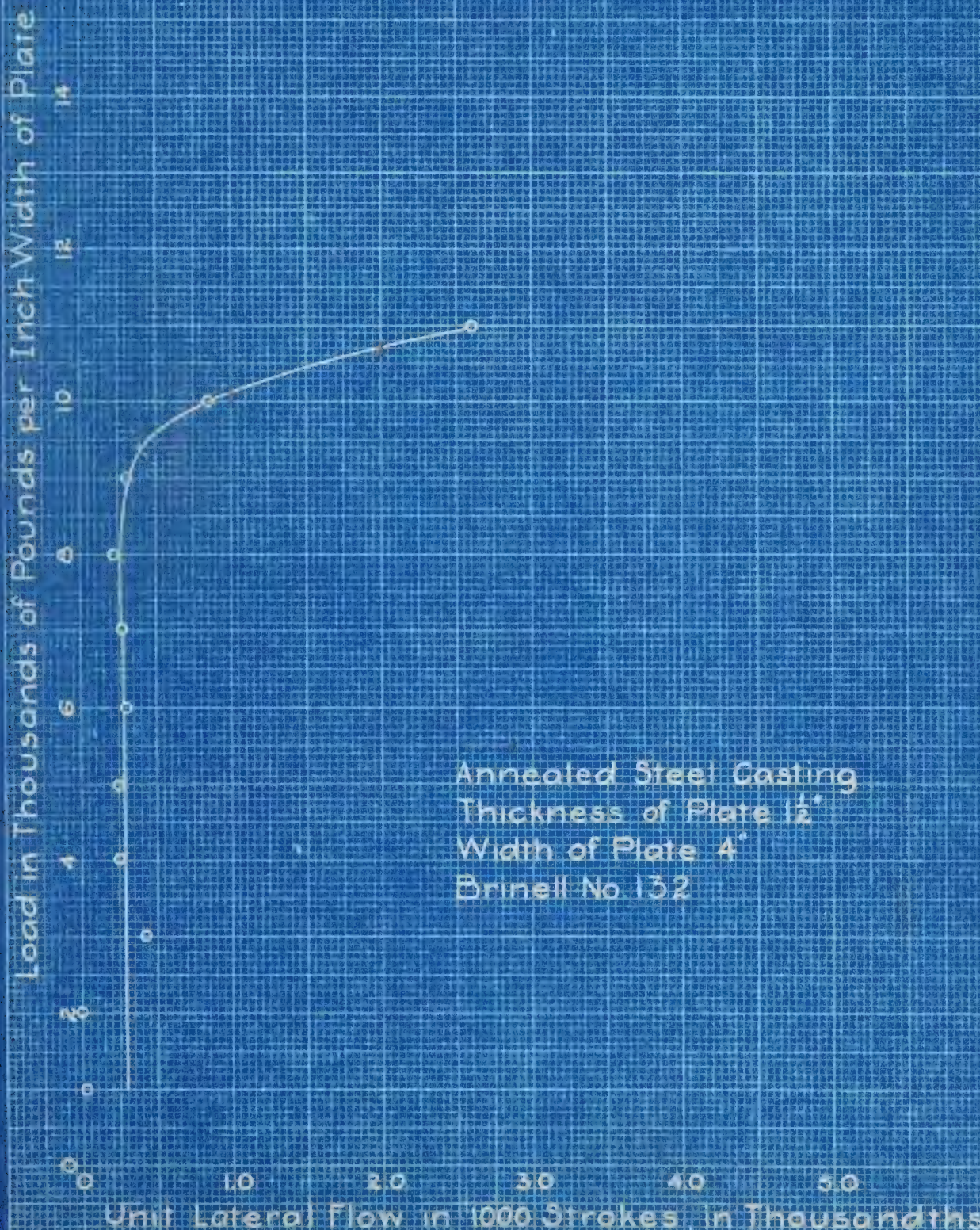
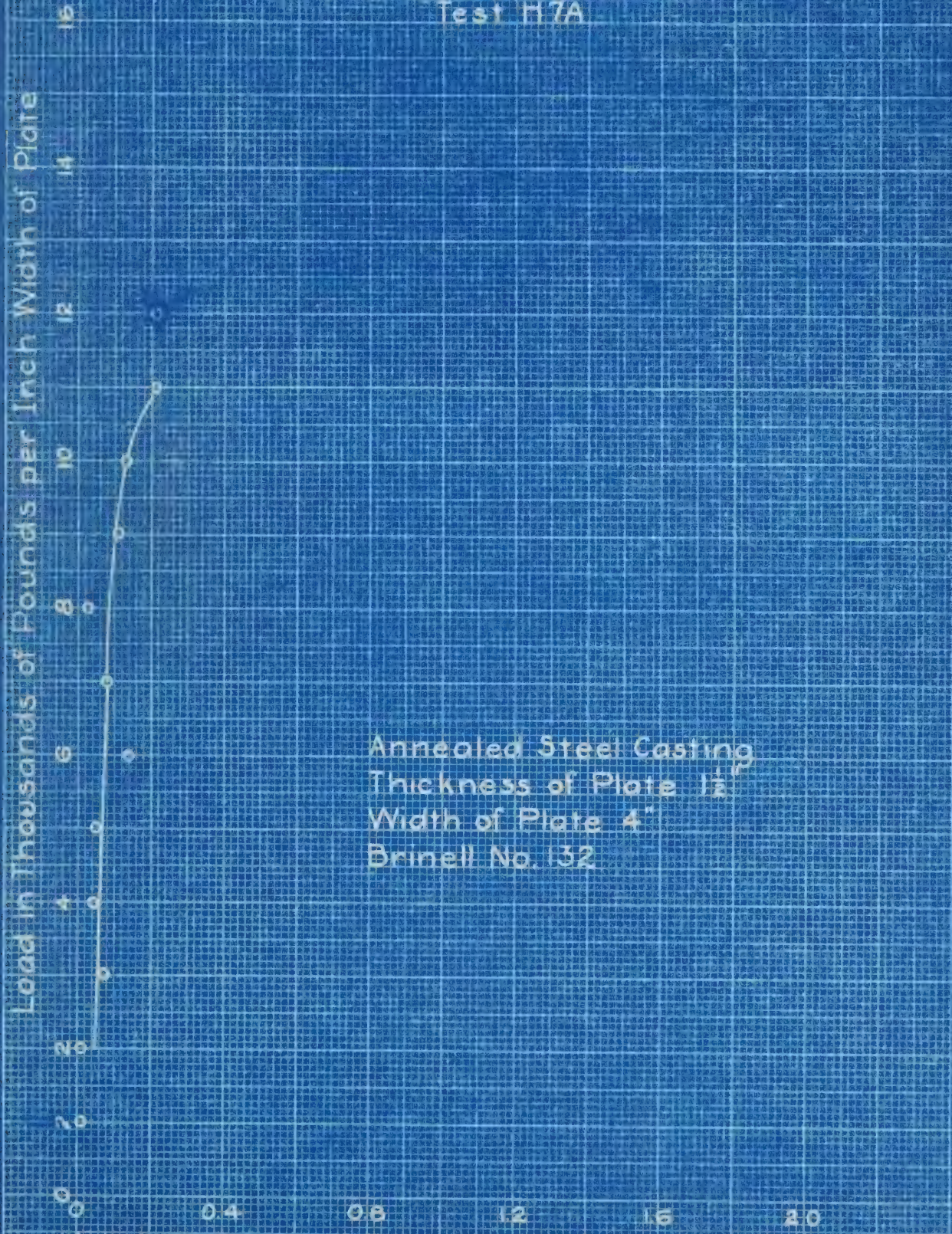


Fig. 27 b
Longitudinal flow of Plate
Due to Rolling
Diameter of Roller 2
Test in 7A



Annealed Steel Casting
Thickness of Plate 1/2
Width of Plate 4
Brinell No. 32

Longitudinal Flow in 1000 Strokes in Thousandths of an Inch

TABLE 2

CRITICAL LOADS

Rolling Tests of Small Rollers

Specimen	Diameter of Roller	Critical Load		
		Lateral Flow	Longitudinal Flow	Spread of Roller
H7A ✓	2	10 100	—	—
H7 ✓	4	11 700	—	11 000
H9 ✓	6	9 500	—	—
H5A ✓	8	10 600	—	11 900
H3A ✓	10	10 100	12 000	11 400
H3 ✓	12	14 500	15 700	8 200
H5 ✓	16	15 200	13 300	14 900
H2 ✓	23½	21 600	22 000	21 800
H1 ✓	23½	21 800	21 100	22 500
H13	36	21 700	19 800	—
H12	68	22 100	30 000	—
H11	92	29 300	30 000	—
H10	116	34 500	33 300	—
H14	116	34 000	33 000	—

3. Discussion. The critical loads as determined by the methods described on page 34 are given in Tables 2&3. The values of the critical loads for rollers larger than 1 1/8 inch in diameter are taken from Professor Wilson's tests on large rollers as reported in Table 3 of Bulletin 191 of the Engineering Experiment Station of the University of Illinois.

In the discussion that follows, the value of the critical load is that determined by the lateral flow of plate and is the load at which the lateral flow is 0.001 of an inch per inch.

The writer has developed the equation of a line that approximates the experimental values very closely. It is

$$P = \left(\frac{p - 13000}{23000} \right) (3360 \sqrt{D})$$

where P is the critical load in pounds per inch width of plate, p is the yield point strength of the material in tension in pounds per square inch and D is the diameter of the roller in inches.

The writer was influenced in developing this equation by the equations proposed by:

Professor Wilson, $P = \left(\frac{p - 13000}{23000} \right) (18000 + 120D)$, where P is the critical load in pounds per inch width of plate, p is the yield point strength of the material in tension and D is the diameter of the roller in inches.

Messrs. Brown and Hartmann, $P = (4000 + 12D) \sqrt[3]{D}$ where P and D are as defined above.

The effect of the yield point strength of the material was studied by Professor Wilson. The factor $\left(\frac{p - 13000}{23000} \right)$ seems to take care of the effect of the properties of the material very well.

The line representing the equation developed by the author is compared with the experimental data in Figure 28a and Figure 28b, the latter being a large scale diagram for rollers less than 36 inches in diameter.

The design formula for the safe load on a steel roller should give values less than those determined as critical loads in this investigation. A factor of safety of 3/2 is not thought too conservative. The formula for the safe load on steel rollers of medium grade steel casting recommended by the author is

$$P = \left(\frac{p - 13000}{23000} \right) (2440 \sqrt{D}),$$

where P is the safe load in pounds per inch width of plate, p is the yield point strength of the material in tension and D is the diameter of the roller in inches.

It is an open question whether or not smaller loads than these values of the critical load would have produced excessive flow had these plates not suffered some cold working by being rolled at smaller loads. The critical load for the 10 inch roller is 10,100 pounds per inch width of plate and is next the smallest of the entire series. That block received less cold working than any other specimen, having been rolled only 4000 strokes at various loads when the critical load was reached. The 8 inch roller with a critical load of 12,600 pounds per inch of width received 7000 strokes at various loads less than the critical load.

An effect of rolling is to increase the hardness of the specimen. The Brinell number for the rolled portion is several points higher than for the unrolled portion. Rolling seems to

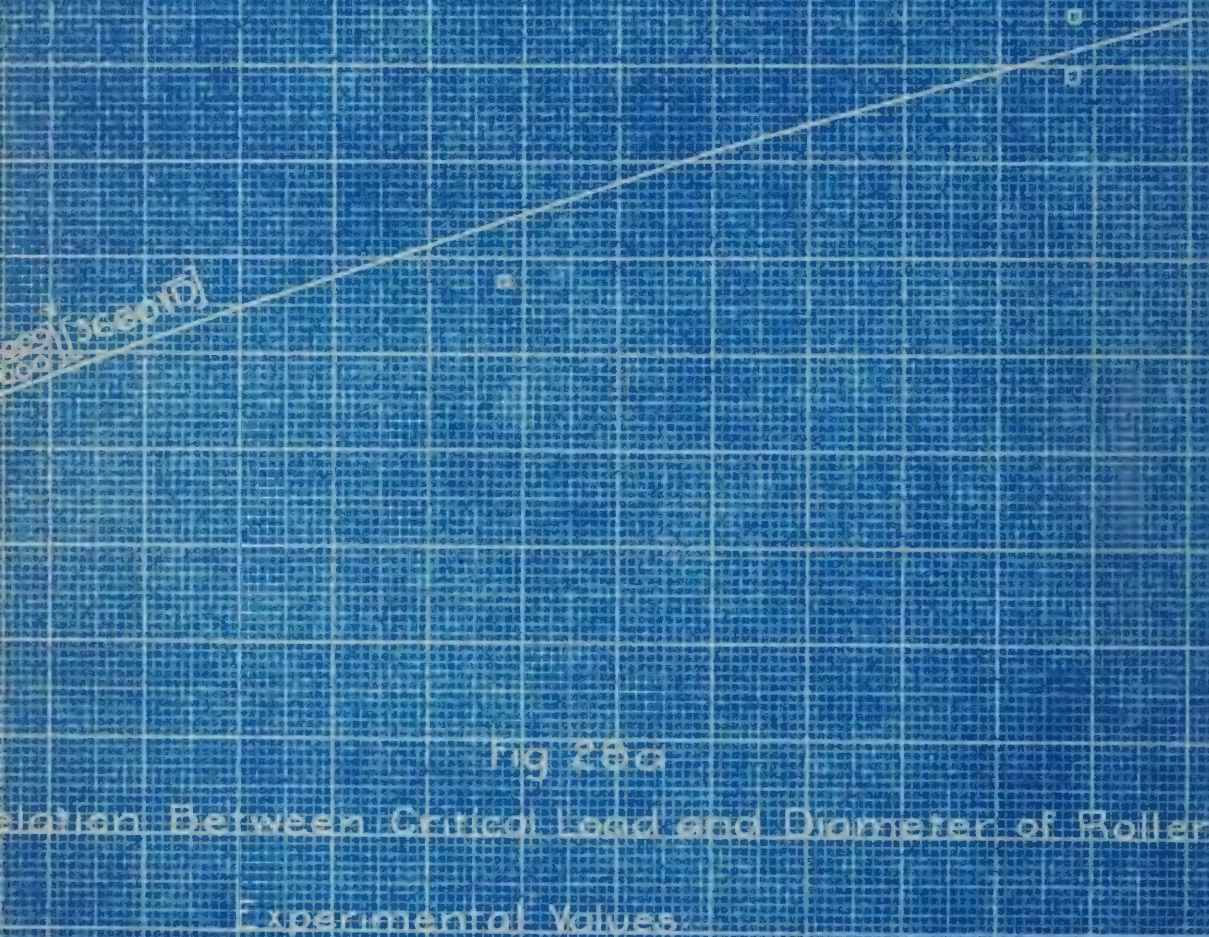


Fig. 26c

Relationship Between Critical Speed and Diameter of Roller

Experimental Values

Wilson's
Formula

Rp. 34,000

300

350

400

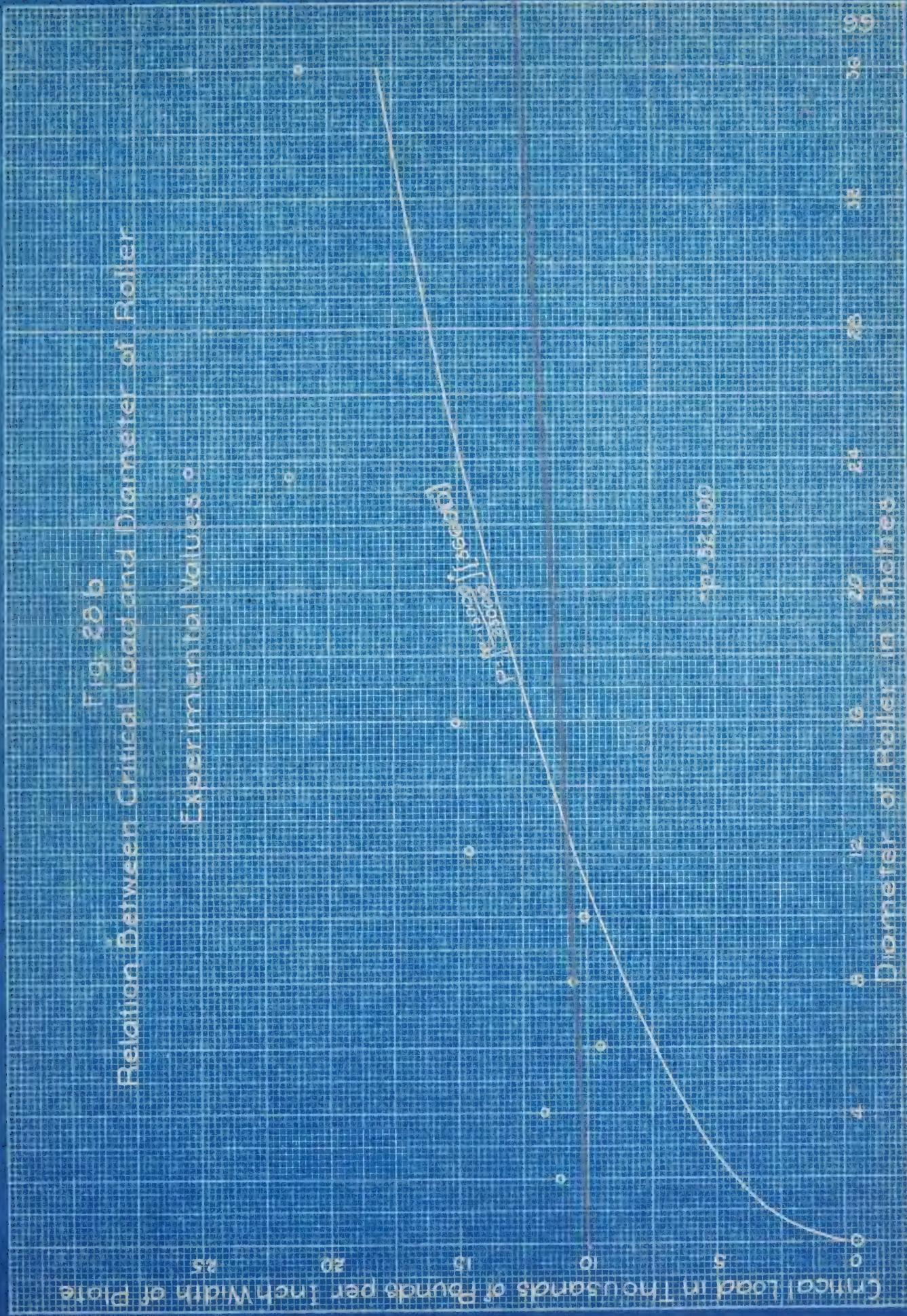
450

500

520

Diameter in Inches

五、**“三不”原则**：不公开、不透明、不公正。这是“三不”原则，也是“三不”原则。



Critical Load in Thousands of Pounds per Inch Width of Plate

Deflection in Inches

10-foot long plate

Yield Load

Ultimate Load

Critical Load

have increased the hardness of the specimen through its entire depth, the unrolled portion of H5A and H7A having a higher Brinell number than H5 and H7 respectively.

VIII. Comparison with Results
of Others.

VIII. COMPARISON WITH RESULTS OF OTHERS.

1. Discussion. The author's design formula and the design formulas proposed by other writers are compared in Figure 29.

It is seen from Figure 29b that the formula $P = 600D$ gives values of the design load that are dangerously great for values of D greater than 24 inches.

The author's design formula allows higher working loads than the formulae of Professor Wilson, and Messrs. Brown and Hartmann for diameters from 36 inches to 220 inches. For diameters greater than 220 inches the author's design formula gives values greater than the formula of Professor Wilson and less than allowed by Messrs. Brown and Hartmann. The use of any of the three proposed formulae will give loads that can be safely rolled on a plate of medium grade steel casting having a rectangular cross-section.

Table 3 gives a comparison of the design load with the experimentally determined critical load. The values of the critical load for tests not performed in this investigation are taken from Table 9, Bulletin 191 Engineering Experiment Station of the University of Illinois. They were determined in the manner described in this thesis. All the plates had rectangular sections and were $1\frac{1}{2}$ inches thick. The values of the critical load for the A and E series are small. The specimens were defective in that they had blow holes along their vertical centerline. Test #14 of this series was similar to the F series reported here. The critical load from the lateral flow of Test #14 is 34000 pounds per inch width of plate while from the E series it is only 25,400

pounds per inch of width. The proposed design load for rollers 2 inches or 4 inches in diameter are probably very conservative.

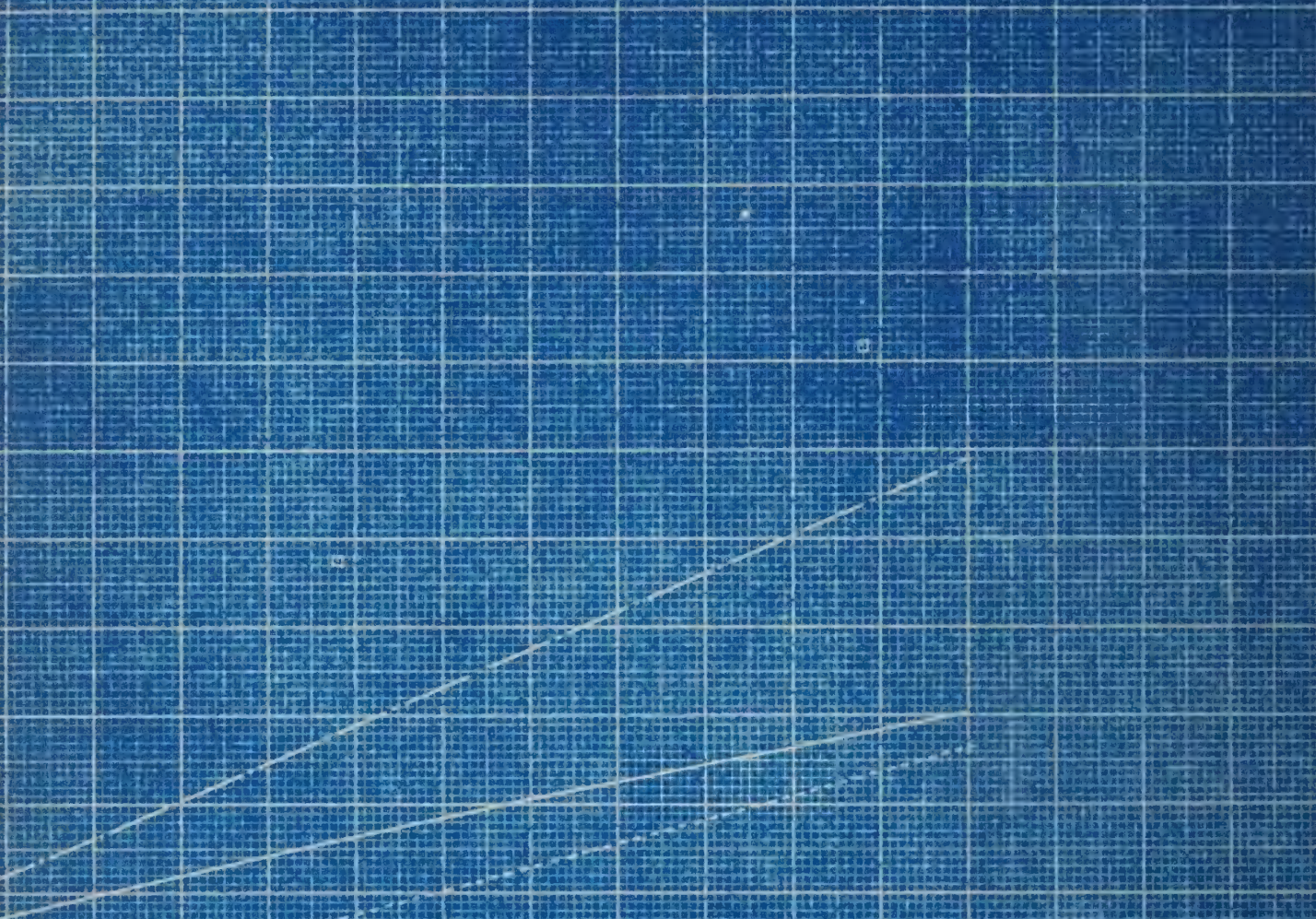


Fig. 29a

Comparison of Proposed Design Formulas

 $P = 600D$
 $\text{Wilson: } P = \left[\frac{P_{1000}}{1.5625} \right] (12000 + 600D)$
 $\text{Brown \& Neumann: } P = 6000 + 90VD$
 $\text{Holt: } P = \left[\frac{P_{1000}}{2.5000} \right] 2440VD$

Experimental Values by: Wilson &

Holt &

 $p = 32,000$

Design Load in Thousands of Pounds
 Diameter of Roller in Inches

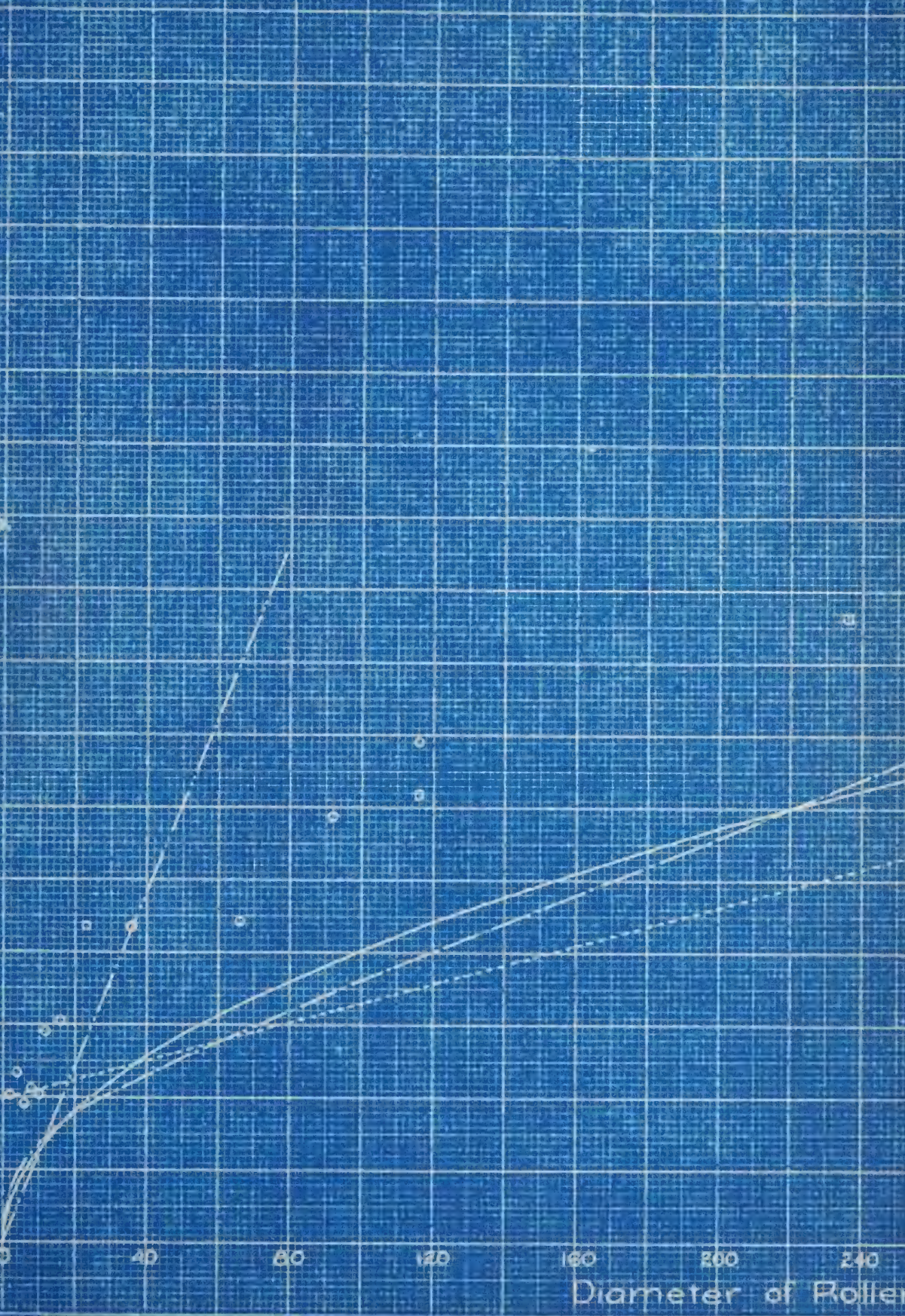


Fig. 49.b Comparison of Proposed Design Formulas

P-6000
Wilson, P-15000 (15000-100)
Brown & Holtzman, P-6000-8000
Holt, P-15000 (14400)
Experimental Values
P-32000

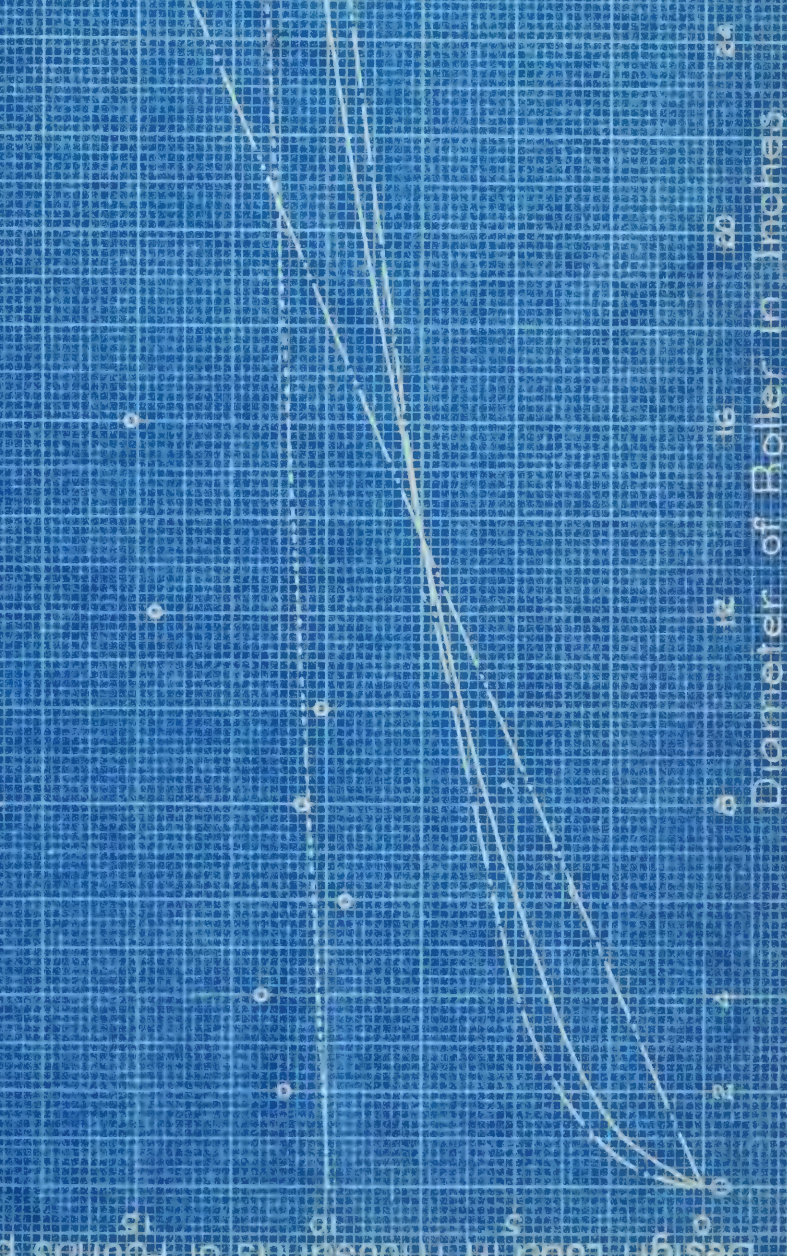


Table 3

Comparison of Proposed Design Load
with Experimentally Determined Critical Load

Series	Diameter	Yield Point	Design Load	Critical Load		%Design Load of Critical Load
				from Lateral Flow	from Longitudinal Flow	
H	2	32,060	2860	10,100		28
	4	32,060	4050	11,700		34
	6	33,600	5350	9,500		56
	8	32,790	5950	10,600		56
	10	31,880	6340	10,100	12,000	63
	12	31,880	6950	14,500	15,700	53
	16	32,790	8400	15,200	13,300	55
	23½	32,500	10,000	21,600	21,500	46
	36	30,760	11,300	21,500	18,800	52
	68	30,920	15,700	22,100	30,000	71
	92	30,800	18,200	29,300		62
	116	31,500	22,300	34,250	33,150	65
E	116	34,533	24,400	25,400	30,700	
A	188	30,869	26,000	24,050	29,650	
F	116	31,900	21,600	31,000	32,000	70
	236	32,600	32,000	43,000	42,500	74
	356	31,200	36,400	54,300	52,700	67
	476	31,900	43,800	66,000	63,300	67
F Hardened	236	56,000	70,000	80,000	70,000	88
	356	57,023	88,200	105,000	100,000	84
	476	56,500	100,100	144,500	142,500	70
L	116	31,377	21,000	22,500	24,000	93
	236	23,664	17,300	19,900	22,250	87
	356	"	21,200	28,950	28,850	73
	476	"	24,600	31,000	30,975	79
LA	116	45,631	37,300	47,200	45,550	79
	236	45,380	52,700	73,750	63,750	72
	356	46,685	67,500	88,750	82,250	76
M	356	31,219	38,500	51,500	47,500	75
C	236	43,505	49,800	59,500	61,000	84
HYLC	236	57,663	72,800	105,000	106,000	69

IX. CONCLUSIONS.

IX. CONCLUSIONS.

1. Conclusions. The tests upon which these conclusions are based were made on rollers varying in diameter from 2 inches to 476 inches and on plates of medium grade steel casting 1½ inches thick having a rectangular cross-section. The conclusions are as follows:

a. During rolling there is a flow of metal in the plate in the direction of and normal to the plane of rolling.

b. When the plate and roller are made of similar material there is a flow of metal in the roller in the direction of its axis.

c. The hardness of the material, indicated by the Brinell hardness test, is greater after a rolling test than before.

d. The design formula $P = 600D$ gives values which are too small for rollers less than 14 inches in diameter and dangerously great for rollers larger than 24 inches in diameter.

e. The experiments justify the use of the following formula for the design of rollers bearing on plates of medium grade steel casting having a rectangular cross-section and a thickness of 1½ inches or more;

$$P = \left(\frac{p - 13000}{23000} \right) (2440 \sqrt{D})$$

where P is the design load in pounds per inch width of plate, p is the yield point strength of the material in tension, and D is the diameter of the roller in inches.

f. The use of any of the three proposed design formulae* give results that can be safely rolled on plates of medium grade steel

*Formulae by Wilson, Brown and Hartmann, and Holt.

casting having a rectangular cross-section and a thickness not less than $1\frac{1}{2}$ inches. However, the author's formula approximates the experimentally determined critical loads more closely than either of the others.

PART II.

ADDITIONAL STUDIES.

PART II.

I. THE EFFECT OF THICKNESS OF PLATE ON
THE CRITICAL LOAD.

PART II. ADDITIONAL STUDIES.

I. THE EFFECT OF THICKNESS OF PLATE ON THE CRITICAL LOAD.

1. Foraword. Professor Wilson made five series of tests to determine a relation between the thickness of plate and the critical load. The thicknesses studied varied from $\frac{1}{2}$ inch to 4 inches and the diameter of roller varied from 118 inches to 476 inches. The relation between the critical load from longitudinal flow and thickness of plate was found to be constant for the range of thicknesses studied. The only inconsistency was in the test of 4-inch plates rolled under a 476 inch roller. The load-deformation curves indicate that the longitudinal flow began at the top of the plate before it did at the bottom, the opposite of what occurred in the thinner plates. From that, it seems that the critical load from longitudinal flow governs as long as that flow first occurs at the bottom of the plate. The relation between critical load from lateral flow and thickness of plate was found to increase with the thickness, reach a maximum and decrease with a further increase in thickness.

The following discussion taken from Bulletin 191 of the Engineering Experiment Station may have some bearing on the relation between the thickness of plate and the critical load from lateral flow. The lateral flow is a maximum at the rolled surface and decreases rapidly with the depth from the top. A thin plate has a tendency to flow throughout its entire depth while the highly stressed material in a deeper plate is reinforced by the under-

stressed material just below. At the same time, the outside corner is supported entirely by the shearing resistance on an inclined plane. The portion of the specimen supported by the shear on inclined planes increases with the depth but at a decreasing rate. The result is a combination of the two effects.

The purpose of this series was to study the effect of the thickness of plate through a wide range.

2. Description of Test. The plate was a portion of a medium grade steel casting which had been annealed. It was from the same heat as the other specimens for rolling tests. A large blow-hole extended through the plate along its vertical center line. The chemical properties are: C, 0.283; S, 0.043; Si, 0.046; Mn, 0.496. The physical properties determined from standard tensile tests are given in Table IV.

At the beginning of the test, the plate was $8\frac{1}{2}$ inches thick. After each test, the rolled portion was cut off, the plate refinished and tested again. The thicknesses of plate tested were $8\frac{1}{2}$ inches, $7\frac{1}{4}$ inches, $6\frac{1}{2}$ inches, $5\frac{1}{2}$ inches, $4\frac{1}{2}$ inches, $3\frac{1}{2}$ inches, $2\frac{1}{2}$ inches, $1\frac{3}{8}$ inches. The portion removed was at least 1 inch thick and thought thick enough to remove all the metal which had received any permanent deformation. Tensile test specimens were cut from the portion removed. The specimen from the rolled portion was taken 2 inches from the lateral center line in order to avoid material adjacent to the defect. The specimen from the unrolled portion was taken $\frac{3}{4}$ inch from the end of the specimen.

Table 4

PHYSICAL PROPERTIES OF PLATES

Rolling Tests of Thick Plates

Specimen	Before Rolling						After Rolling					
	Ultimate Strength	Yield Point	Elongation in 2 inches	Reduction of Area	Brinell Number		Ultimate Strength	Yield Point	Elongation in 2 inches	Reduction of Area	Brinell Number	
A17	67,430	30,880	22.60	25.70	139		67,090	36,390	11.80	11.30	142	
A18	67,350	30,750	21.20	22.94	129		67,610	39,950	13.25	18.32	141	
A19	67,340	30,330	21.69	22.30	131		65,290	31,200	13.62	14.36	141	
A20	67,460	30,410	19.32	21.62	133		65,173	32,990	12.12	15.61	138	
A21	67,020	30,390	19.37	22.27	135		65,357	32,130	12.83	14.84	144	
A22	67,140	30,710	17.74	21.01	131		65,970	32,710	11.87	13.76	140	
A23	67,140	30,020	19.00	21.47	127		64,697	32,247	13.00	17.01	140	

The apparatus used for this series of tests was that used by Professor Wilson in his study of large rollers and is described on page 14. The diameter of roller was 116 inches.

The deformations were measured with the micrometer and strain gage described on page 21. The procedure of testing large rollers described on page 34 was followed in this series of tests, except that the specimens were rolled 2000 strokes at each load instead of 1000.

3. Results. The results of this study are given in the curves of Figures 30 to 36 inclusive.

In plates that are thick in proportion to the diameter, the critical load from lateral flow governs the bearing value while the critical load from longitudinal flow governs for thin plates. The thickness of plate which gives equal critical loads from lateral and longitudinal flow, as determined by Professor Wilson, is 1 inch + $0.004D$ which in this case is 1.46 inch. This is borne out by these tests in which the lateral flow governs in all cases except for the thinnest plate which is 1.37 inches thick.

The critical load is interpreted to be that load at which the lateral flow is 0.001 inches per inch in 2000 strokes.

The effect of rolling is to increase the Brinell number of the rolled portion. The effect of rolling at one thickness seems to have no effect on the hardness of the material at the depth of the next rolled surface. If the effect of rolling at one thickness had an effect on the hardness of the material throughout the block, the thinnest plate would be expected to have the largest Brinell number whereas it has the smallest.

Fig. 30a

Lateral Flow of Annealed Steel Casting Due to Rolling

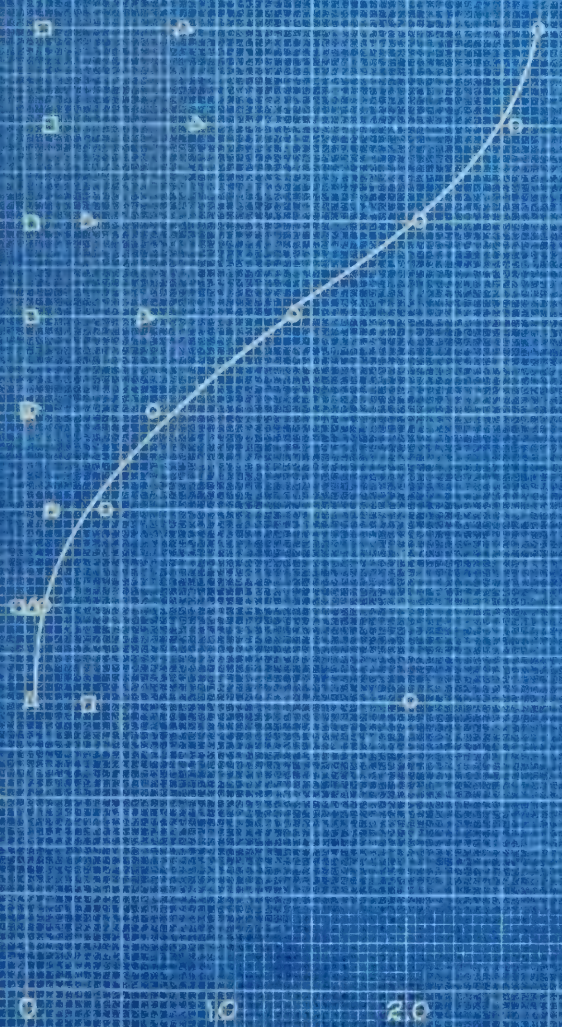
Diameter of Roller 16"
Width of Plate 4"
Thickness of Plate 0.3"
Brinell No. 139

Test A17

Legend

- Flow 8" from top of Plate
- Flow 16" from top of Plate
- Flow 24" from top of Plate

Lead in thousands of pounds per inch width of plate

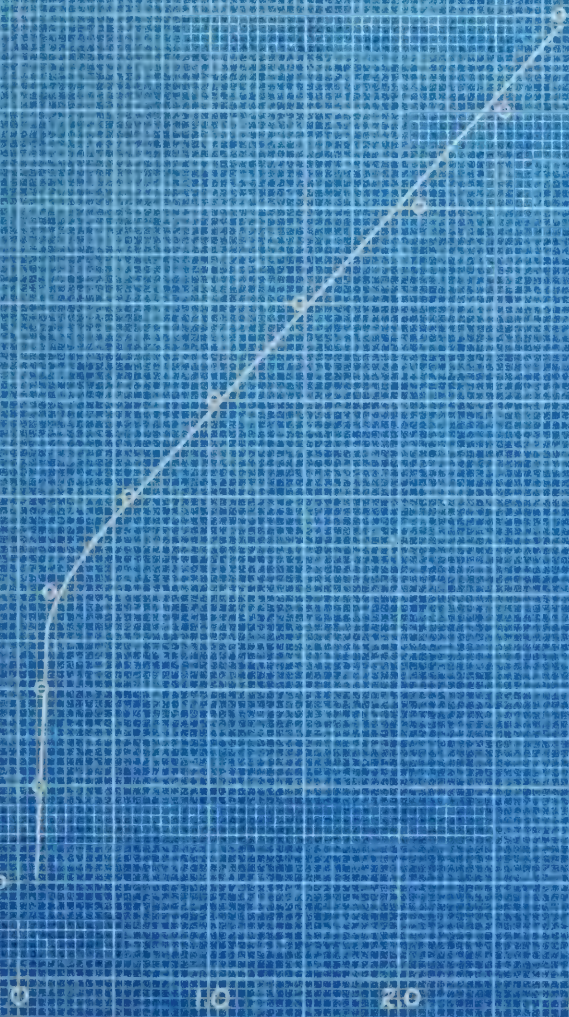


Unit Lateral Flow in 2000 Strokes in thousands of lbs

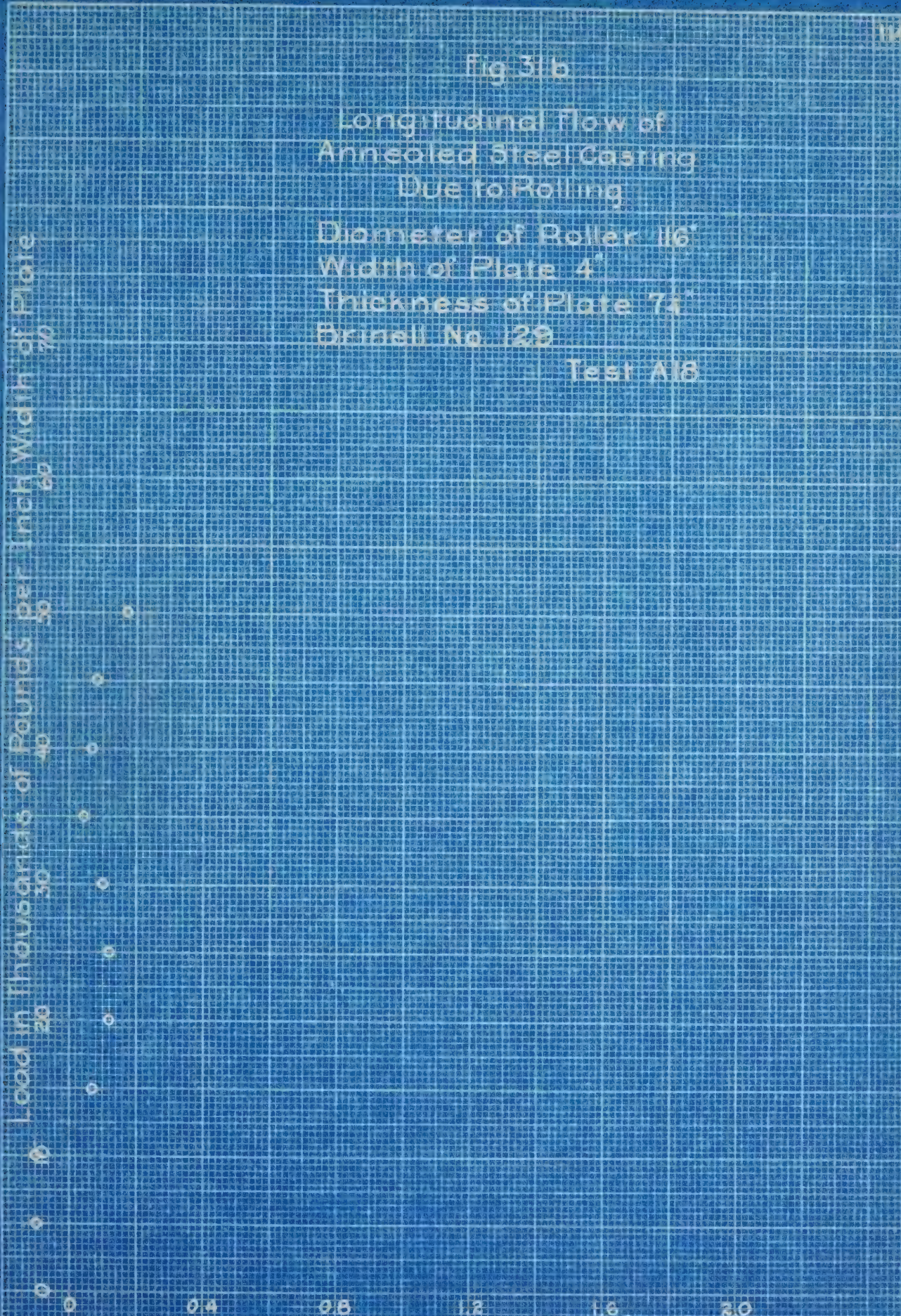
No. 319
 Lateral Flow of
 Annealed Steel Casting
 Due to Rolling
 Diameter of Roller 16
 Width of Plate 4
 Thickness of Plate 7.1
 Brinell No. 129

Test A16

100
 90
 80
 70
 60
 50
 40
 30
 20
 10
 0



Lateral Flow in 2000 Strokes in Thousandths



Longitudinal Flow in 2000 Strokes
Annealed Steel Plate No. 10
Due to Rolling
Diameter of Roller 16
Width of Plate 4
Thickness of Plate 1/2
Rolling No. 22

Unit Longitudinal Flow in 2000 Strokes in Thousandths

Fig 32a

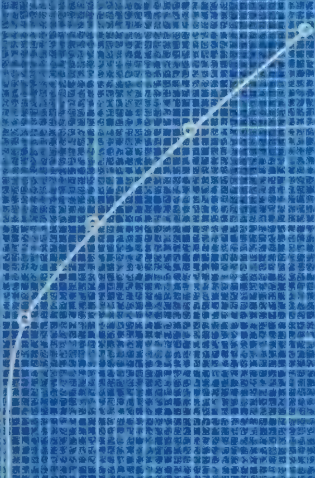
Lateral Flow of Annealed Steel Casting Due to Rolling

Diameter of Roller 16"
Width of Plate 4"
Thickness of Plate 6"
Brinell No 131

Test A19

Lead in Thousands of Pounds per Inch Width of Plate

70
60
50
40
30
20
10
0



0
1
2
3
4
5
6
7

Lateral Flow in 2000 Strokes in Thousandths

Don't Use a New Car Keep the Old One Due to Emissions

Diameter of Roller 16
Width of Plane 14
Thickness of Blade 15
Drivell No. 13

1990年11月12日

[illegible]

Unit-Lock High-Capacity Flow in 2000: 5.3 GPM @ 150 PSI

Fig. 33a

Lateral Flow of Annealed Steel Coasting Due to Rolling

Diameter of Roller 16"

Width of Plate 4'

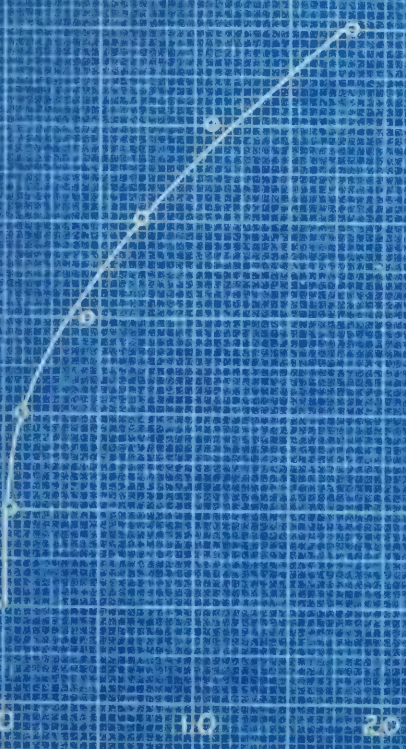
Thickness of Plate 4 1/2"

Roller No. 25

Test A 20

Coasting in thousands of pounds per inch width of plate

60
50
40
30
20
10
0



Lateral flow in 2000 strokes in thousandths of an inch

0 10 20 30 40 50

Flow in
 Longitudinal Flow by
 Arterial Stenosis
 Diameter of Roller
 Width of Plate
 Thickness of Plate
 Initial No. of
 Back Arteries

0.0
 0.1
 0.2
 0.3
 0.4
 0.5
 0.6
 0.7
 0.8
 0.9
 1.0
 1.1
 1.2
 1.3
 1.4
 1.5
 1.6
 1.7
 1.8
 1.9
 2.0
 2.1
 2.2
 2.3
 2.4
 2.5
 2.6
 2.7
 2.8
 2.9
 3.0
 3.1
 3.2
 3.3
 3.4
 3.5
 3.6
 3.7
 3.8
 3.9
 4.0
 4.1
 4.2
 4.3
 4.4
 4.5
 4.6
 4.7
 4.8
 4.9
 5.0
 5.1
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 6.8
 6.9
 7.0
 7.1
 7.2
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 7.5
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 7.7
 7.8
 7.9
 8.0
 8.1
 8.2
 8.3
 8.4
 8.5
 8.6
 8.7
 8.8
 8.9
 9.0
 9.1
 9.2
 9.3
 9.4
 9.5
 9.6
 9.7
 9.8
 9.9
 10.0

0.0 0.4 0.8 1.2 1.6 2.0
 Unit Longitudinal Flow in 2000 Strokes in Thousands

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100 101 102 103 104 105 106 107 108 109 110 111 112 113 114 115 116 117 118 119 120 121 122 123 124 125 126 127 128 129 130 131 132 133 134 135 136 137 138 139 140 141 142 143 144 145 146 147 148 149 150 151 152 153 154 155 156 157 158 159 160 161 162 163 164 165 166 167 168 169 170 171 172 173 174 175 176 177 178 179 180 181 182 183 184 185 186 187 188 189 190 191 192 193 194 195 196 197 198 199 200 201 202 203 204 205 206 207 208 209 210 211 212 213 214 215 216 217 218 219 220 221 222 223 224 225 226 227 228 229 230 231 232 233 234 235 236 237 238 239 240 241 242 243 244 245 246 247 248 249 250 251 252 253 254 255 256 257 258 259 260 261 262 263 264 265 266 267 268 269 270 271 272 273 274 275 276 277 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Fig 35a

Lateral flow of Annealed Steel Casting Due to Rolling

Diameter of Roller 116"

Width of Plate 4"

Thickness of Plate 2 1/4"

Binnell No. 11

Test A 22

Lateral flow in thousandths of an inch per inch width of plate

70

60

50

40

30

20

10

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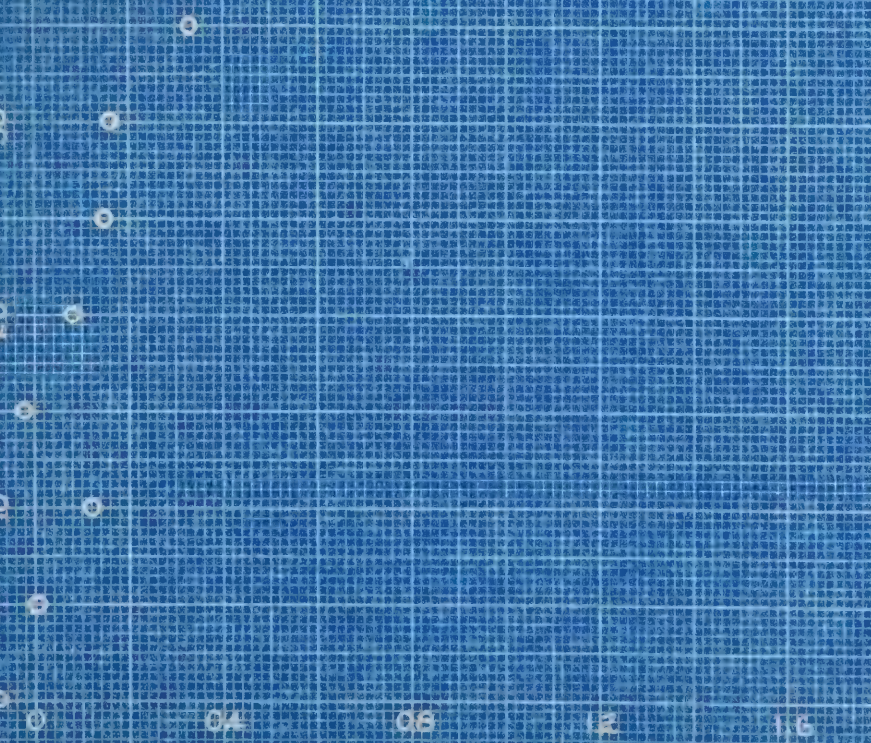
90

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Unit Lateral Flow in 2000 Strokes in Thousandths of an Inch

Fig. 3.5.16
Longitudinal flow of
Annealed Steel casting
Due to Rolling
Diameter of Roller 16"
Width of Plate 4"
Thickness of Plate 2.5"
Brinell No. 13
Test A-32

Plate Width 4"



Longitudinal flow in 2000 strokes in 100 seconds

[illegible]

Flow on Top

1. 项目概况：本项目为某大型商业综合体，总建筑面积约100,000平方米，包括购物中心、写字楼、酒店及住宅等。项目位于市中心繁华地段，交通便利，周边配套设施完善。

[illegible]

2010年12月25日，在“2010年中国年度人物”颁奖典礼上，中国首位“80后”航天员刘洋，作为唯一的女航天员，成为全场瞩目的焦点。刘洋在颁奖典礼上表示，她将不负众望，为祖国的航天事业贡献自己的一份力量。刘洋的当选，不仅是中国航天事业的骄傲，也是中国女性力量的象征。刘洋在颁奖典礼上表示，她将不负众望，为祖国的航天事业贡献自己的一份力量。刘洋的当选，不仅是中国航天事业的骄傲，也是中国女性力量的象征。

在 2008 年 12 月 1 日以前，如果公司已经收到 2008 年 12 月 1 日以前已经到期的应付账款，那么公司应当在 2008 年 12 月 1 日以前，按照应付账款的账面余额，借记“应付账款”科目，贷记“应付账款”科目。如果公司已经收到 2008 年 12 月 1 日以后到期的应付账款，那么公司应当在 2008 年 12 月 1 日以后，按照应付账款的账面余额，借记“应付账款”科目，贷记“应付账款”科目。

1. 凡在本行開辦之各項業務，均應遵守本行所訂之各項規章，並應隨時注意本行所訂之各項規章，如有違反者，本行將依法究辦。

1. 本行在 2015 年 12 月 31 日及 2016 年 6 月 30 日，均無任何逾期或违约情况。本行在 2015 年 12 月 31 日及 2016 年 6 月 30 日，均無任何逾期或违约情况。本行在 2015 年 12 月 31 日及 2016 年 6 月 30 日，均無任何逾期或违约情况。

[illegible][illegible][illegible]

Figure 1. The effect of the concentration of the polymer solution on the apparent viscosity of the polymer solution. The apparent viscosity of the polymer solution increases with the concentration of the polymer solution. The apparent viscosity of the polymer solution is higher at a higher concentration of the polymer solution.

2016年12月31日 星期六

Now 2,000 Strokes

Table 5

Critical Loads

Rolling Tests of Thick Plates
Diameter of Roller 116"

Test	Thickness of Plate	Critical Load
A17	8 $\frac{1}{2}$ "	32 000
A18	7 $\frac{1}{4}$ "	30 000
A19	6"	30 000
A20	4 $\frac{3}{4}$ "	28 000
A21	3 $\frac{3}{4}$ "	27 000
A22	2 $\frac{3}{4}$ "	29 000
A23	1 $\frac{3}{8}$ "	28 500

The yield point of the material was increased by the cold working effect in every case whereas the ultimate strength was decreased except in AIS where it increased very slightly. The reduction of area and percent elongation was less in the tensile specimens taken from the rolled portion than those from the unrolled portion.

The values of the critical load determined by lateral flow are given in Table V. It appears that the thickness of plate when greater than $(1 + .004D)$ inches has little or no effect on the critical load.

PART II.

II. ELASTIC FLOW.

II. ELASTIC FLOW.

1. Forwrd. The time consumed in the rolling process of a single test averaged about 13 hours. A method of determining the critical load from elastic flow would be of great advantage because the number of strokes at each load could be reduced from 1000 or 2000 to a very few in the short period required to observe the elastic flow and a large part of the cold working effect would also be eliminated. These tests were made to study the elastic flow of plate and develop a method of determining the critical load from the elastic flow.

Measurements for permanent and elastic lateral and longitudinal flow were made on the plates tested in the study of the effect of thickness of plate on the critical load.

2. Description of Test. This study was made at the same time as the study of the thickness of plate. The specimen, apparatus, and procedure of test are described under that study.

In addition, measurements were made for elastic lateral and longitudinal ^{flow} of plate. The measurement of elastic lateral flow is described on page 23. The elastic longitudinal flow was measured by holding the strain gage in the gage holes while the roller was in motion. The difference in the reading when the roller was at the end and middle of the stroke is interpreted to be the elastic longitudinal flow of the plate.

3. Results. The relation between load and the permanent flow

of plate is shown in Figures 30 to 36 inclusive. The relation between load and the elastic flow of plate is shown in Figures 37 to 44 inclusive.

The curves for elastic flow in thick plates indicate no "break" whereby a critical load can be determined. In the two thinnest plates the elastic flow increases, reaches a maximum, and decreases. The maximum elastic flow in the plate $1\frac{3}{8}$ inches thick occurs at a load of 30,000 pounds per inch width of plate while the critical load from permanent longitudinal flow is 25,000 pounds per inch of width and from permanent lateral flow it is 23,200 pounds per inch of width. The maximum elastic lateral flow in the plate $2\frac{3}{4}$ inches thick occurs at a load of 25,000 pounds per inch width of plate while the critical load from permanent lateral flow is 22,600 pounds per inch width of plate.

For the range of thicknesses studied the elastic flow gives no satisfactory criterion for determining the critical load. There is, however, an indication that for thinner plates, the elastic flow may indicate the critical load.

Fig. 316

Elastic Lateral Flow of Annealed Steel Casing Due to Rolling

Diameter of Roller 16"
Width of Plate 4"
Thickness of Plate 8 1/2"
Brinell No. 139
Test A17

Load in Thousands of Pounds per Inch Width of Plate

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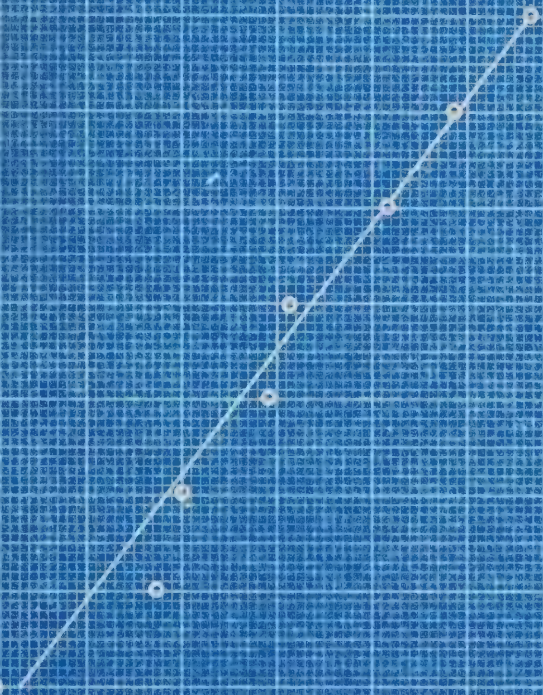
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Unit Elastic Lateral Flow in Thousandths



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Unit Plastic Lateral Flow of Annealed Steel Casting Due to Polishing

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Barrett, No. 19

Unit Plastic Lateral Flow in Households

Fig. 39b

Elastic Longitudinal Flow of Annealed Steel Casting Due to Rolling

Diameter of Roller 16"
Width of Flare 4"
Thickness of Flare .6"
Drill Hole No. 1
Test A19

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Elastic Longitudinal Flow in Thousandths

Fig. 4.10a

Elastic Lateral Flow of Annealed Steel Casting During Rolling

Brinell No. 135
Diameter of Roller 16
Width of Plate 4
Thickness of Plate 4
Test A 20

Load in Pounds per Inch Width of Plate

0

10

20

30

40

50

Unit Elastic Lateral Flow, in thousandths

Diameter of Well = 116
 Width of Pipe = 24
 Thickness of Pipe = 42
 Inside No. 36

傅星洲 邵佩 范繼張 廖金 齊雲 高景 吳 德 我 寧 寧
定 昭 國 華 瑞 沈 玉 鍾 松 彭 洪 金 羅 謝 鄭 黎 鄧 廖
周 又 經 楊 瑞 希 廖 州 宏 齊 陳 李 謝 潘 吳 洪 成 瑞 寧

[illegible]

Unidirectional Longitudinal Flow in Theysoneffs

Fig. 416

Pressure Lateral Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller, 16"
Width of Plate, 4"
Thickness of Plate, 3/8"
Brinell No. 35

Test A-21

Load in Thousands of Pounds per Inch Width of Plate

80
60
40
20
0

0 10 20 30 40 50

60 70 80 90 100

110 120 130 140 150

160 170 180 190 200

210 220 230 240 250

260 270 280 290 300

310 320 330 340 350

360 370 380 390 400

410 420 430 440 450

460 470 480 490 500

510 520 530 540 550

560 570 580 590 600

610 620 630 640 650

660 670 680 690 700

710 720 730 740 750

760 770 780 790 800

810 820 830 840 850

860 870 880 890 900

910 920 930 940 950

960 970 980 990 1000

1010 1020 1030 1040 1050

1060 1070 1080 1090 1100

1110 1120 1130 1140 1150

1160 1170 1180 1190 1200

1210 1220 1230 1240 1250

1260 1270 1280 1290 1300

1310 1320 1330 1340 1350

1360 1370 1380 1390 1400

1410 1420 1430 1440 1450

1460 1470 1480 1490 1500

1510 1520 1530 1540 1550

1560 1570 1580 1590 1600

1610 1620 1630 1640 1650

1660 1670 1680 1690 1700

1710 1720 1730 1740 1750

1760 1770 1780 1790 1800

1810 1820 1830 1840 1850

1860 1870 1880 1890 1900

1910 1920 1930 1940 1950

1960 1970 1980 1990 2000

2010 2020 2030 2040 2050

2060 2070 2080 2090 2100

2110 2120 2130 2140 2150

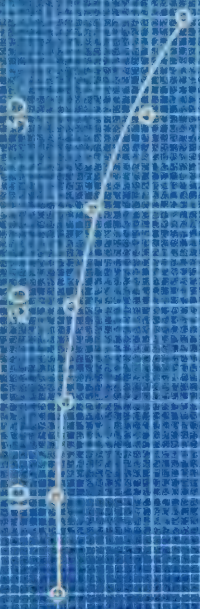
2160 2170 2180 2190 2200

Unit Pressure Lateral Flow in the Tensile

Elastic Longitudinal Flow of Annealed Steel Cooling Due to Rolling

Diameter of Roller 16"
Width of Plate 4
Thickness of Plate 3 1/4"
Brinell No. 135
Test A21

Lead in Thousands of Pounds per Inch Width of Plate



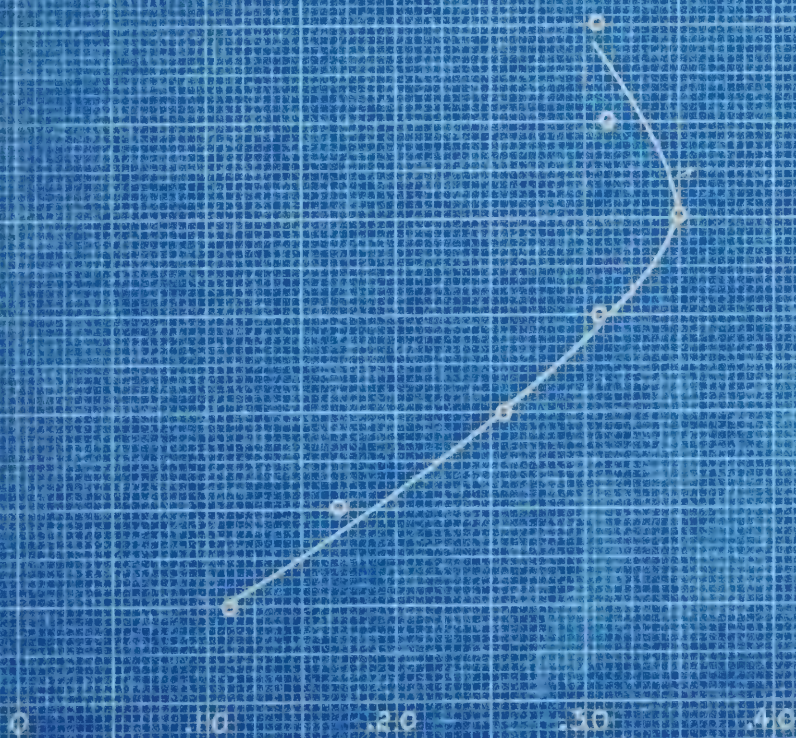
Unit Elastic Longitudinal Flow in Thousands of In

Fig 42a

Elastic Lateral Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller 16"
Width of Plate 4"
Thickness of Plate 2 1/4"
Brinell No. 131

ASTM A22

Load in thousands of pounds per inch width of plate



Unit Elastic Lateral Flow, in Thousands of Pounds per Inch Width of Plate

Fig 42 b

Elastic Longitudinal Flow of Annealed Steel Casting Due to Rolling

Diameter of Roller 116"
Width of Plate 4'
Thickness of Plate 2 1/4"
Brinell No 131

Test A42

Load in Thousands of Pounds per Inch Width of Plate

80
60
40
20
0



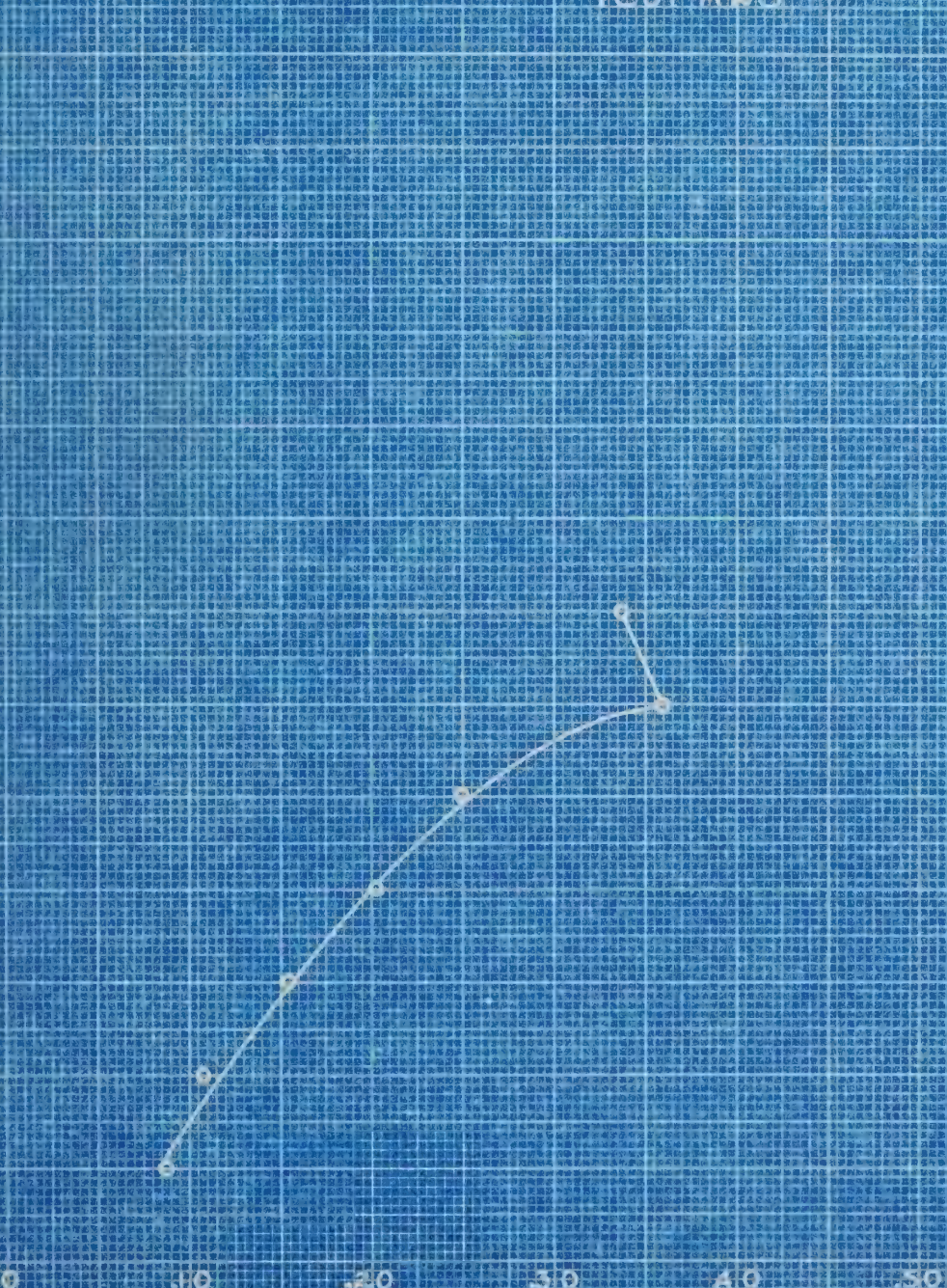
0.4 0.8 1.2 1.6 2.0

Elastic Longitudinal Flow in Thousandths

Fig. 43a
Elastic Lateral Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller, 10"
Width of Plate, 4"
Thickness of Plate, $\frac{1}{8}$ "
Channel No. 127

Test Area

0 10 20 30 40 50 60 70 80 90 100
Elastic Lateral Flow in Thousandths



0 10 20 30 40 50 60 70 80 90 100
Elastic Lateral Flow in Thousandths

Elastic Longitudinal Flow of Annealed Steel: Costing Due to Rolling

Diameter of Roller No.
Width of Plate, in
Thickness of Plate, in
Drum No. 12

See A2.3

Lead in Thousands of Pounds per Inch Width of Plate

0 10 20 30 40 50 60



Unit Elastic Longitudinal Flow, in Thousands of Inches

0 0.4 0.8 1.2 1.6 2.0

PART II.

III. THE CARRYING CAPACITY OF A STEEL CASTING
HAVING AN H-SECTION.

III. THE CARRYING CAPACITY OF A STEEL CASTING HAVING AN H-SECTION.

1. Foreword. Usually sole plates have a rectangular cross-section. According to the equations of Hertz, the plane of maximum stress occurs a small distance from the bearing surface. The remainder of the material is understressed, part of which can be considered idle metal.

By using very thick sole plates the rolling load is distributed over a greater length of the supporting girders. The thickness of plate giving the maximum resistance to lateral flow as determined by Professor Wilson is $1 \text{ inch} + 1.0045$ which in the case of a 40 foot roller is 2.92 inches. A sole plate as thin as that would not distribute the load very well to the supporting girder and one thicker than that would waste material. It seems that, by using a casting with an H-section, part of the idle material of a thick plate could be removed. The casting could also be more easily attached to the supporting girders.

This study was undertaken to develop a method of determining the carrying capacity of a steel casting having an H-section.

2. Method of Analysis. A semi-rational analysis was undertaken. Such a method must necessarily be based on certain assumptions regarding the distribution of loads on the flange to the web and the distribution of stress in the web.

It was assumed that the center line of the area of contact in the direction of the axis of the roller remained a straight line. This necessitates that the flanges of the roller and sole plate be

identical. This assumption is justified by the argument that due to symmetry the flanges will deflect symmetrically about the plane tangent to the roller through the center line of the area in contact.

A load on the flange was assumed to be distributed over a length of web, l , equal to the width of the area in contact, a , plus the distance from the load point to the edge of the web, d , plus the thickness of the flange, t , all divided by the square of the thickness of the flange, or $l = \frac{a + t + d}{t^2}$. The stress over this length was assumed uniform. Or the assumption may be stated that the maximum stress in the web is equal to the average stress over the assumed length of web.

The influence line for stress calculated on this assumption is shown in Figure 44.

By the use of Hertz' formula

$$a = 0.004\sqrt{PD},$$

the width of area in contact, a , can be calculated where P is the load per inch width of plate and D is the diameter of the roller in inches.

The displacement of the center line of the contact area relative to the base of the plate, neglecting the deformation in the web of the casting, is made up of two parts. They are:

(a) A deformation in the material due to the contact of the roller and plane surface. Prescott gives the equation for the depth of this impression as

$$w = - \frac{(1 - \mu)P_0}{2n} \cdot b$$

Position on Load
1 2 3 4 5 6 7 8 9 10 11 12

Web

100

200

300

400

500

600

700

800

900

1000

1100

1200

1300

1400

1500

100

200

300

400

500

600

700

800

900

1000

1100

1200

1300

1400

1500

100

200

300

400

100

200

300

400

100

200

300

400

100

200

300

400

100

200

300

400

100

200

300

400

These Due to Local Road Conditions

These Due to Local Road Conditions

These Due to Local Road Conditions

where w = the depth of the impression

m = Poisson's ratio

P_0 = the maximum unit pressure between cylinder and plate

n = modulus of elasticity in shear.

b = one half the width of area in contact.

(b) Deflection of the flange. The author made an extensive search for an equation giving this quantity but found none. The magnitude of this quantity is very small. An assumption of its magnitude unless very exact may give results very much in error. It seems that the deflection might vary inversely as a power of the thickness of the flange.

Tests were made on a medium grade steel casting having an H-section and the following dimensions to determine the deflection of the loaded flange,

length 10 inches

height ,back to back of flanges, 12 inches

flange width 10 inches

flange thickness 0.83

web thickness 0.81

The surfaces were machined and the fillet between flange and web removed.

Equal loads were placed on the flange symmetrically about the web. The bearing blocks on the flange were $\frac{1}{2}$ " x 1", the long side being parallel to the web. The deflection was measured at 4 pairs of points with dials mounted so the plunger bore on the under surface of the flange. The deflection $\frac{1}{2}$ inch from the web was measured with a dial of the Last Word type in which one division

on the dial represents .0001 inch movement of the plunger. The deflection at other points was measured with Ames dials in which one division of the dial represents 0.001 inch movement of the plunger. In both cases, parts of a division were estimated. The load points were $\frac{1}{2}$ inch apart on the transverse center line of the flange. They were numbered from 0 to 9, 0 being over the web and 9 being near the edge of the flange. The set up is shown by the photographs in Figure 45. Influence lines for deflection were gotten by measuring the deflection at various points with the load at the load points. These lines are given in Figure 46.

The problem is to determine the distribution of load across the flange so that the impression of the roller plus the deflection of the flange is constant and still keep the unit stress within the allowable. Let the conditions of the problem be:

flange width $4\frac{1}{2}$ inches

flange thickness 0.83

web thickness 0.81

diameter of roller 18'9"

Poisson's ratio 0.30

modulus of elasticity in shear 12,000,000 pounds
per square inch

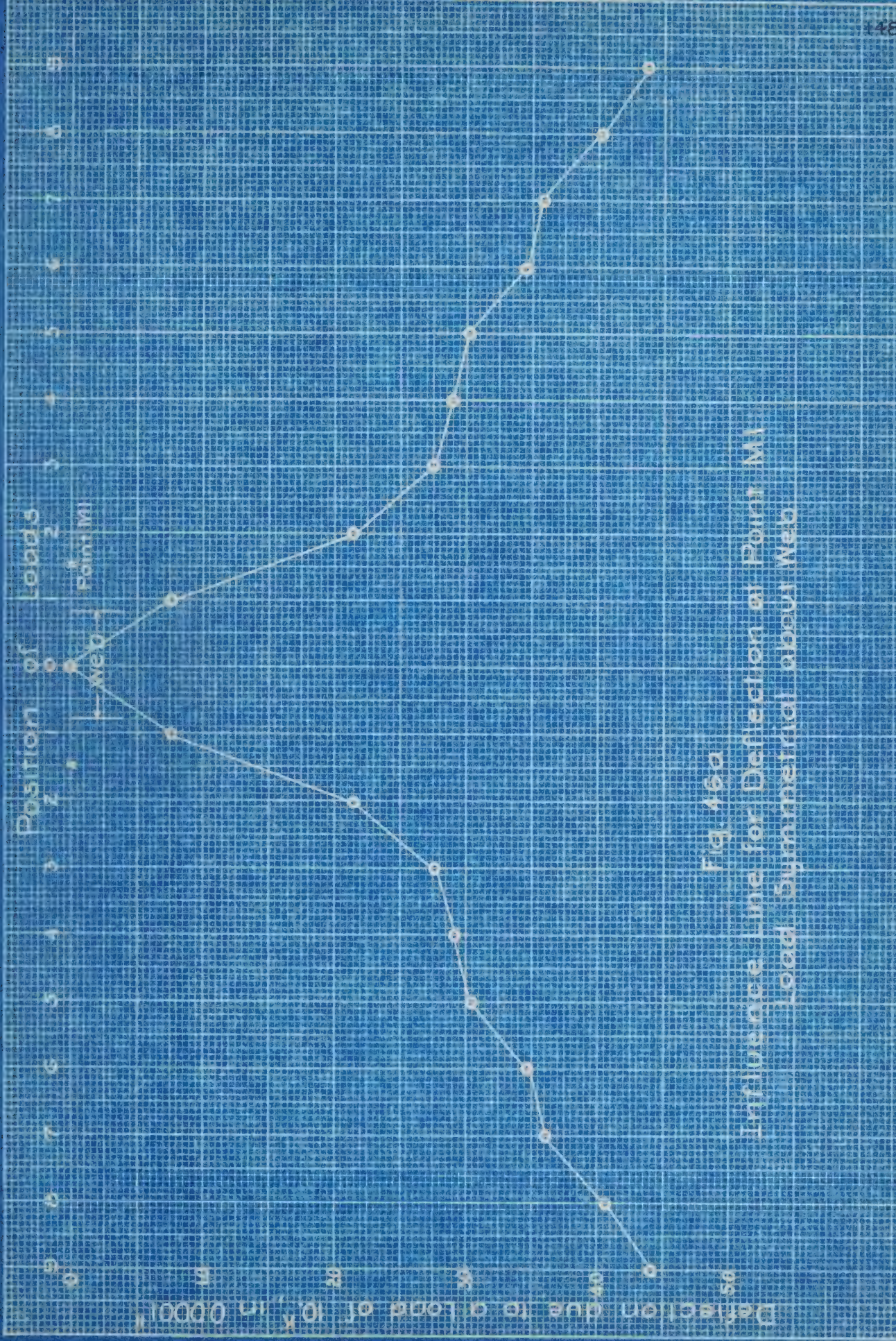
elastic limit strength of material in tension =
32000 pounds per square inch.

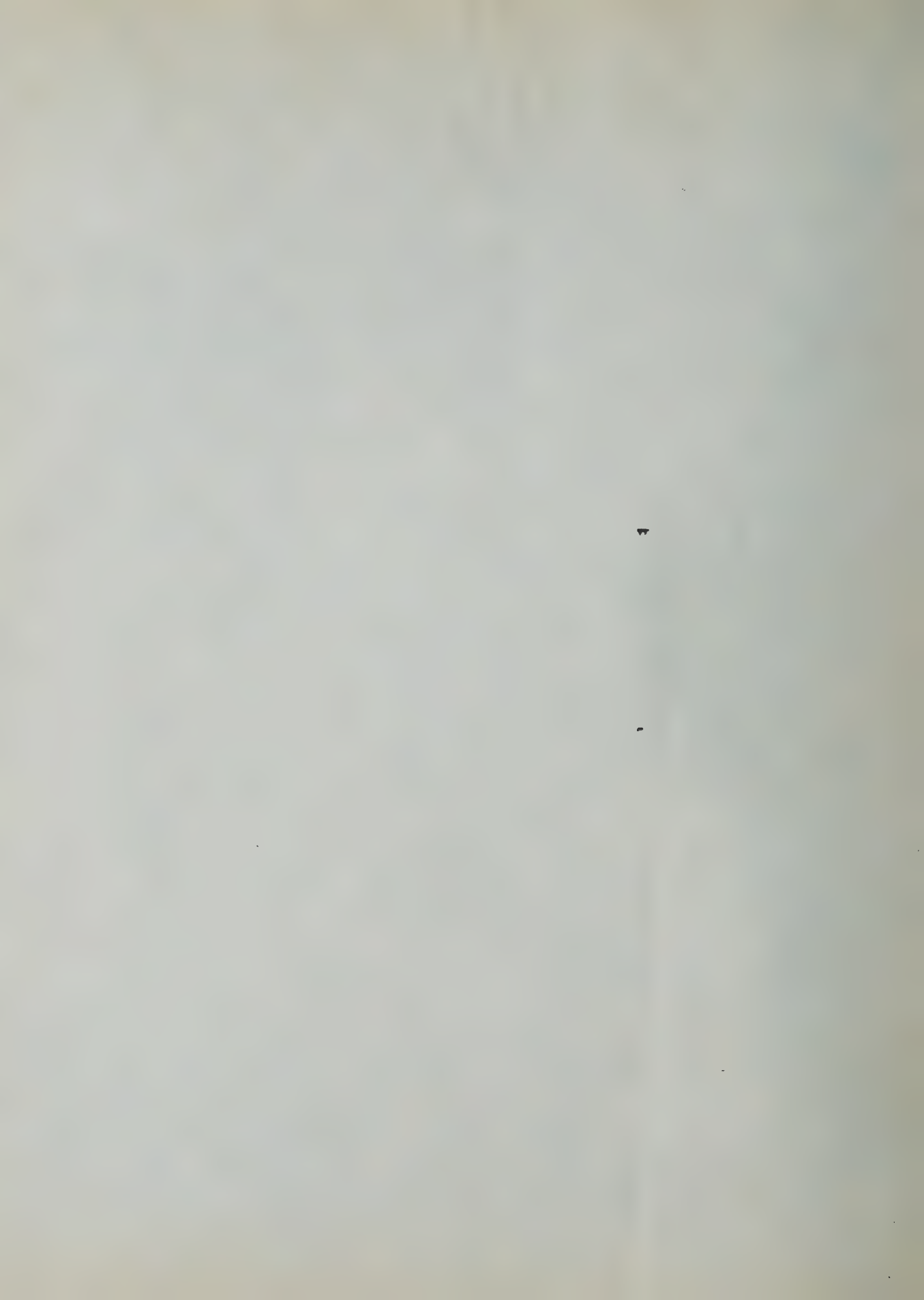
Assume a distribution of load and calculate the depth of impression over the web and at the points where deflection was measured. If the impression plus the deflection is constant, the distribution is correct. The next thing to do is calculate the



Fig. 45

Set-up for Measuring the Deflection of the Flange
of a Steel Casting having an H-Section





stress. If the stress is near the allowable, the assumed loading is the capacity of the casting.

The procedure of calculation is as follows:

Assume a distribution of load across the flange,

9 at $\frac{1}{2}$ " = $4\frac{1}{2}$ "
load points

4	3	2	1	0	1	2	3	4
5.8	10.3	12.7	14.0	14.4	14.0	12.7	10.3	5.8 = 100
load in thousands of pounds								

$$a_0 = 0.0004 \sqrt{P_0} = 0.006 \sqrt{14,400} = 0.720$$

$$P_0 = \frac{2 \times 14,400}{\pi \times .36} = 25,500$$

$$w_0 = \frac{.7 \times 25,500}{2 \times 12 \times 10^6} \times .36 = .000268$$

$$a_H = 0.006 \sqrt{5,800} = 0.457$$

$$P_H = \frac{2 \times 5800}{\pi \times 0.228} = 16,200$$

$$w_H = \frac{.7 \times 16,200}{2 \times 12 \times 10^6} \times .228 = .000108$$

$$\Delta \text{ due to load at 4} = .001160$$

$$\text{" " " " " 3} = .001854$$

$$\text{" " " " " 2} = .001164$$

$$\text{" " " " " 1} = .000420$$

$$\text{" " " " " 0} = 0$$

$$.004598 + .000108 = .004706$$

$$\text{Stress in web due to load at 0} = 6,580$$

$$\text{" " " " " 1} = 11,860$$

$$\text{" " " " " 2} = 8,550$$

$$\text{" " " " " 3} = 5,720$$

$$\text{" " " " " 4} = 2,760$$

$$35,470 \text{ lb. per sq. in.}$$

The material is overstressed. The influence line for stress says to place heavier loads farther from the web and the influence line for deflection says to put heavier loads over the web. Both conditions cannot be satisfied at once. Therefore the specimen will not carry 100,000 pounds.

Reduce the load.

$$9 \text{ at } \frac{1}{2}'' = 4\frac{1}{2}''$$

4	3	2	1	0	1	2	3	4
4.0	7.2	9.0	9.8	10	9.5	9.0	7.0	4.0

$$a_0 = 0.006 \sqrt{10,000} = 0.6$$

$$P_0 = \frac{2 \times 10}{\pi \times 0.3} = 21,200$$

$$w_0 = \frac{.7 \times 21,200}{24 \times 10^6} \times 0.3 = .000185''$$

$$a_4 = 0.006 \sqrt{4000} = 0.38$$

$$P_4 = \frac{2 \times 4}{\pi \times .19} = 13,400$$

$$w_4 = \frac{.7 \times 13,400}{24 \times 10^6} \times 0.19 = .000074$$

$$\Delta \text{ due to load at 4} = .000237$$

$$" \quad " \quad " \quad 3 = .000405$$

$$" \quad " \quad " \quad 2 = .000443$$

$$" \quad " \quad " \quad 1 = .000184$$

$$" \quad " \quad " \quad 0 = 0$$

$$.001369 + .000074 = .001443$$

stress in web due to load at 0 = 4,570

" " " " 1 = 8,050

" " " " 2 = 6,050

" " " " 3 = 4,770

" " " " 4 = 1,900

25,340 lb. per sq. in.

The stress is all right but the distribution of load is in error. The deflection at M_2 is too great; put heavier loads near the web.

Assume this distribution of load:

4	3	2	1	0	1	2	3	4	= 60k
0	0	5	11	28	11	5	0	0	

$$a_0 = 0.006 \sqrt{28,000} = 1.001$$

$$p_0 = \frac{2 \times 28,000}{\pi \times .5} = 37,000$$

$$w_0 = \frac{7 \times 37,000}{2 \times 12 \times 10^6} \approx .50 = .000540$$

$$a_4 = 0.006 \sqrt{5000} = .434$$

$$p_2 = \frac{2 \times 5000}{\pi \times .212} = 15,000$$

$$w_2 = \frac{2 \times 15,000}{2 \times 12 \times 10^6} \times .212 = .000093$$

$$\underline{.000460}$$

$$.000553$$

$$\Delta \text{ due to load at 0} = .0$$

$$" " " 1 = .000214$$

$$" " " 2 = \underline{.000346}$$

$$.000460 + .000093 = .000553$$

stress due to load at 0 =	12800
" " " 1 =	19320
" " " 2 =	<u>3360</u>
	25480

It is seen that very light loads at load point 4 cause more deflection than is allowed by the depth of the impression at the web. Evidently there can be no load at point 4. Now, since that point carries no load it may deflect clear away from the roller. In the computations, check the deflection at point M1 against the depth of impression at load point 0.

It is found that a total load of 80,000 pounds distributed thus:

4	3	2	1	0	1	2	3	4
0	0	5	11	28	11	5	0	0

can be safely carried by the section.

It is evident that a section with these dimensions is not of great value as a sole plate. If the flange had been thicker, the section would have been strengthened a great deal. The recommendation of Professor Wilson for flange thickness is $1" + 0.004D$ which in this problem is 1.9".

This problem in itself is only of academic value but the method of attack of the problem may be of some value to the designer of sole plates for rolling lift bridges.

Strains were measured in the web to determine the accuracy of the assumed stress distribution.

Two Huggenberger Tensometers, one on either side of the web, were used to make the measurements of strain in the web for loads on the flange. The tensometer is shown by photograph in Fig. 47.

It is a so-called "fixed instrument". The gage points are knife edges which engage firmly in the material by the force of the clamps which hold the instrument in place. The multiplication ratio of one instrument was 1065 while of the other was 1802. The scale was divided into tenths and readings were estimated to hundredths. One division on the scale represented a change of the gage length of less than 0.001 inch. The size and consistency of the readings indicate they were fairly precise and represented the strains.

It is possible to vary the gage length of the instrument by changing the fixed knife edge. With a gage length of $1\frac{5}{8}$ inch, the fixed knife edge engaged the web about $\frac{1}{32}$ inch from the flange. An influence line for strain on a $1\frac{5}{8}$ inch gage length at the vertical center line of the web was drawn. By changing the gage length to 1 inch and keeping the movable knife edge in the same place, another influence line for strain on a 1 inch gage line was drawn. The difference between the total strain in the two cases is the strain on a $\frac{5}{8}$ inch gage line next to the flange.

The stress in the web was computed from these values of strain assuming $E = 30,000,000$ pounds per square inch. The computations are given in Table 6.

The values of stress thus determined are shown in Figure 44 with the assumed values.



Fig.47

Huggenberger Tensometer

For Measuring Strain in Web of a
Steel Casting having an H-Section

TABLE VI. TENSOMETER READINGS AND STRESS CALCULATIONS.

Load at At Reading	Zero Reading	Loaded Reading	Difference		Increment		Difference in		Total Strain per		Average	
			N	S	N	S	N	S	Unit of Load	x 10 ⁻⁴	Strain	x 10 ⁻⁴
0	.470	.320	.150	.215	.150	.215	.0163	.0262	.1718	.2150	.1949	
1	.410	.095	.315	.340	.315	.340	.0208	.0225	.1553	.1872	.1912	
2	.440	.130	.310	.410	.310	.410	.0155	.0202	.1455	.1650	.1567	
3	.450	.150	.300	.295	.300	.295	.0148	.0146	.1390	.1216	.1303	
4	.460	.215	.245	.200	.245	.200	.0122	.0125	.1146	.1040	.1093	
5	.445	.345	.145	.290	.145	.290	.00725	.0145	.06808	.1206	.0943	
6	.465	.290	.195	.175	.195	.175	.00966	.00868	.09071	.07221	.08146	
7	.490	.310	.180	.160	.180	.160	.00884	.00785	.08301	.06530	.07415	
8	.480	.360	.100	.200	.100	.200	.00500	.0100	.04625	.08319	.06507	
9	.485	.390	.095	.165	.095	.165	.00475	.00825	.04460	.06863	.05661	
0	.400	.300	.100	.135	.100	.135	.00990	.0134	.09296	.11147	.10221	
1	.390	.200	.190	.255	.190	.255	.00950	.01275	.08921	.10607	.09764	
2	.385	.215	.170	.225	.170	.225	.00846	.01120	.07944	.09317	.08630	
3	.400	.260	.140	.205	.140	.205	.00694	.01017	.06516	.08460	.07488	
4	.410	.300	.110	.195	.110	.195	.00542	.00960	.05089	.07986	.06537	
5	.405	.295	.110	.170	.110	.170	.00545	.00843	.05118	.07013	.06065	
6	.400	.290	.110	.145	.110	.145	.00550	.00725	.05165	.06031	.05598	
7	.405	.300	.105	.140	.105	.140	.00523	.00697	.04911	.05798	.05354	
8	.410	.350	.060	.170	.060	.170	.00300	.00650	.02817	.07071	.04944	
9	.380	.300	.080	.130	.080	.130	.00400	.00650	.03756	.05407	.04581	
1 = Gauge length.												
1 1/2 = Gauge length.												
Load at			Strain in 5/8" x 10 ⁻⁴		Unit strain x 10 ⁻⁴		Stress/kip.		E=300000000			
0			.0927	.0927	.1483	.1483	444.9	444.9	444.9	444.9	444.9	444.9
1			.0936	.0936	.1498	.1498	449.4	449.4	449.4	449.4	449.4	449.4
2			.0704	.0704	.1126	.1126	337.8	337.8	337.8	337.8	337.8	337.8
3			.0554	.0554	.08864	.08864	265.9	265.9	265.9	265.9	265.9	265.9
4			.0439	.0439	.07024	.07024	210.7	210.7	210.7	210.7	210.7	210.7
5			.0337	.0337	.05392	.05392	161.8	161.8	161.8	161.8	161.8	161.8
6			.0255	.0255	.04080	.04080	122.4	122.4	122.4	122.4	122.4	122.4
7			.0206	.0206	.03296	.03296	98.9	98.9	98.9	98.9	98.9	98.9
8			.0156	.0156	.02496	.02496	74.9	74.9	74.9	74.9	74.9	74.9
9			.0108	.0108	.01728	.01728	51.8	51.8	51.8	51.8	51.8	51.8

PART II.

IV. THE CARRYING CAPACITY OF STEEL CASTINGS
HAVING SPECIAL SHAPES.

IV. THE CARRYING CAPACITY OF STEEL CASTINGS HAVING SPECIAL SHAPES.

1. Foravori. The objection that sole plates having a rectangular section contain much idle metal is applicable to a sole plate having an H-section. Only that metal at the critical section in either case is stressed to the allowable. The critical section in a rectangular plate is at a small depth from the rolled surface. The critical section in a sole plate having an H-section is in the web next to the flange. The remainder of the metal is understressed.

A plate with a cross section which varies with the length seems to be one in which some of the metal is stressed nearer the allowable.

This study was undertaken to:

- a. Compare the carrying capacity of special shaped steel castings with castings having a solid rectangular section.
- b. Study the effect of the properties of the material on the carrying capacity of the plate.
- c. Study the distribution of strain in a deep casting having a rectangular section.

Rolling tests were made on castings having a V-shaped top flange with and without stiffeners, also on castings having solid rectangular sections. Each shape was made of two materials, carbon steel casting and high manganese steel casting under the trade name of Hylastic Steel. Two depths of rectangular plates were tested,

vis. $1\frac{1}{2}$ inches and $4\frac{3}{4}$ inches. The diameter of roller was 236 inches in all tests.

3. Description of Test. Figure 48 shows the dimensions and shape of each specimen. The castings of Hylastic steel are denoted by the additional letters HYL. The Foundry gave the chemical properties as follows:

	C	S	Si	Mn	P
Carbon Steel Casting	0.30	0.35	0.35	0.70	0.02
Hylastic " "	0.35	0.03	0.40	1.45	0.02

The physical properties are as follows:

	<u>Yield Point</u>	<u>Ultimate Strength</u>	<u>Reduction of Area</u>	<u>Elongation in 2 inches</u>
Carbon Steel Casting	43500	79500	22.7	23.1
Hylastic Steel Casting	57660	103200	42.8	22.8

All the specimens were normalized at the Foundry and received no heat treatment in the laboratory. They were separate castings large enough that $\frac{1}{4}$ inch of material could be removed from all ^{finished} surfaces in finishing the specimen. The rolled surfaces were finished by hand with a file and emery cloth and proved with a machinist's face-plate.

The apparatus used for these tests was that used by Professor Wilson in his study of large rollers and is described on page 14.

The procedure of testing is described on page 34 except that the specimen was rolled 2000 strokes at each load instead of 1000.

Measurements were made for lateral and longitudinal flow as described on page 23. In addition, vertical deformations were measured on a 4 inch gage length. In specimens C31 and HYL31,

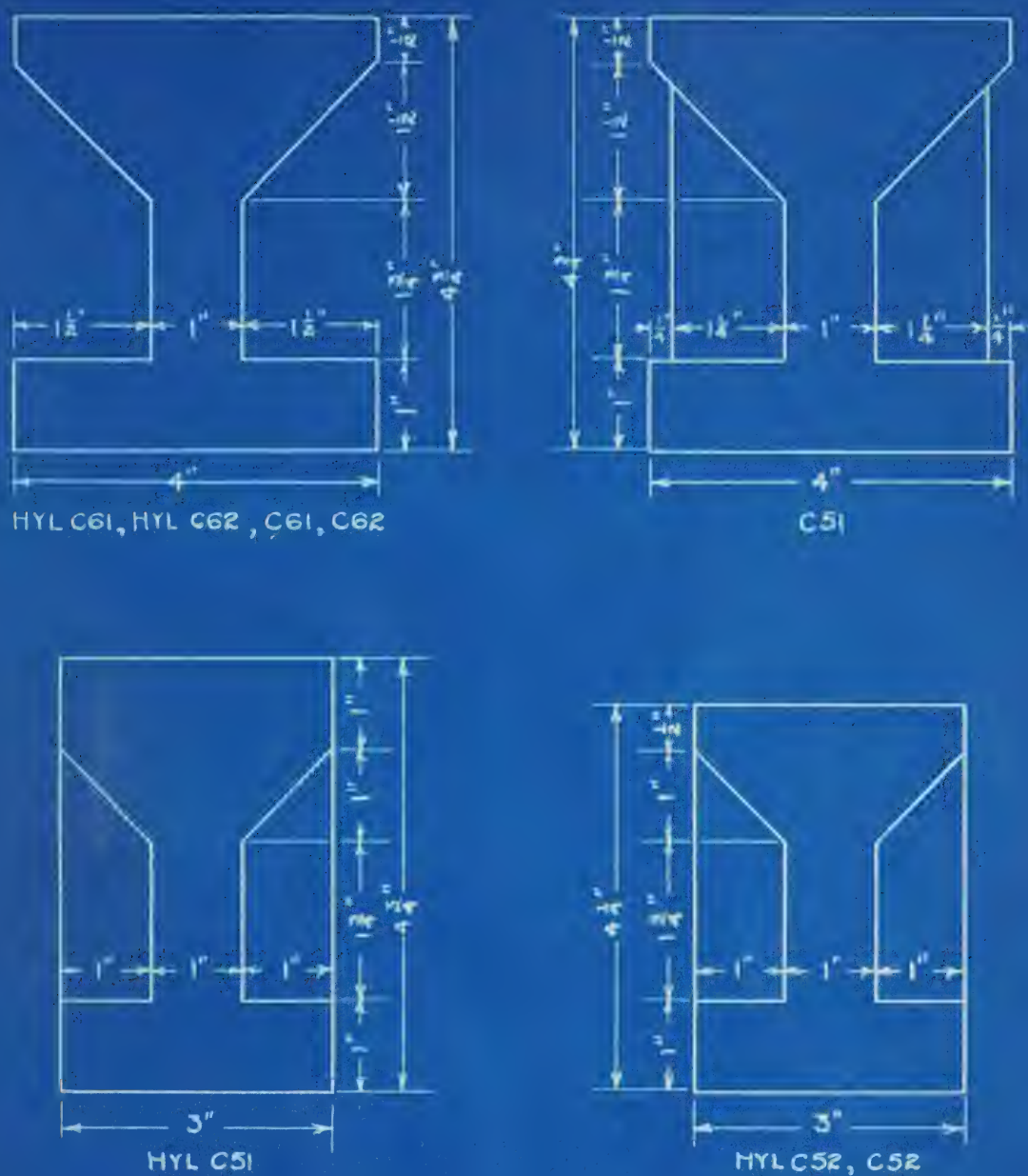


Fig.48
Shape and Dimensions
of
SPECIAL SHAPED CASTINGS

vertical deformations were also measured on a 2" gage length.

3. Results. The results of these tests are shown in Figures 49 to 68 inclusive. The critical load is considered to be that at the break in the curve as at point a Figure 51a.

G31 and NYL G31. These plates had solid rectangular sections 4 inches wide and $4\frac{3}{8}$ inches thick. The load-deformation curves are given in Figures 49 and 50.

The curve for test G31 indicates that the maximum lateral flow occurred at the top of the plate and that very little flow occurred lower than $1/8$ th the depth of the block or $5/8$ inch below the surface. The test on NYL G31 was not carried far enough to determine the critical load.

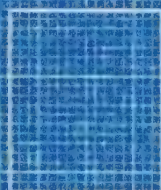
The unit vertical deformation in the top 2 inches is only slightly more than that in the top 4 inches.

The longitudinal flow in neither case was very great and does not give a critical load.

The critical load for G31 determined by lateral flow is 61000 pounds per inch width of plate and from vertical deformation it is 64000 pounds per inch width of plate.



Fig. 49a
Lateral Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller 236
Brinell No. 165
Shape of Casting



10

Test 101

Experience
Flow of Metal



Unilateral Flow of Metal

[illegible]



Fig. 49c
 Vertical Deformation in
 Annealed Steel Casting
 Due to Rolling
 Diameter of Roller 236"
 Brinell No. 165
 Shape of Casting

Vertical Deformation in Inches per Inch Width of Plate
 Diameter of Roller, 236"
 Brinell No. 165
 Shape of Casting

Vertical Deformation in Inches per Inch Width of Plate
 Diameter of Roller, 236"
 Brinell No. 165
 Shape of Casting

100
90
80
70
60
50
40
30
20
10
0

Percentage of pounds per inch width of roller

Fig 50a
Lateral Flow of
Austenitic Steel Casting
Due to Rolling
Diameter of Roller 2.36"
Brinell No. 214
Shape of Casting

100
90
80
70
60
50
40
30
20
10
0

Percentage of pounds per inch width of roller

100
90
80
70
60
50
40
30
20
10
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Percentage of pounds per inch width of roller

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C41, C42, NYL C41, and NYL C42. These specimens had solid rectangular sections 4 inches wide and $1\frac{1}{2}$ inches thick. The load-deformation diagrams are given in Figures 51 to 54.

The critical load from the lateral flow of C41 and C42 is 60,000 pounds per inch of width of plate.

The critical load from the longitudinal flow of C41 and C42 is 61500 pounds per inch of width of plate.

The critical load from the lateral flow of NYL C41 is 104,000 pounds per inch width of plate while from NYL C42 it is 110,500 pounds per inch of width.

The critical load from the longitudinal flow of NYL C41 is 101,000 pounds per inch width of plate while from NYL C42 it is 108,000 pounds per inch of width.

These values of critical load compared with the following results obtained by Professor Wilson with material of different grades tested in the same manner indicate that the grade of the material has a marked effect on the bearing value of a plate.

Carbon Steel Casting (annealed)	45,500 lb. per in. of width.
" " " (hardened)	90,000 " " "
Structural Steel	22,300 " " "

Load in thousands of Pounds per Inch Width of Plate

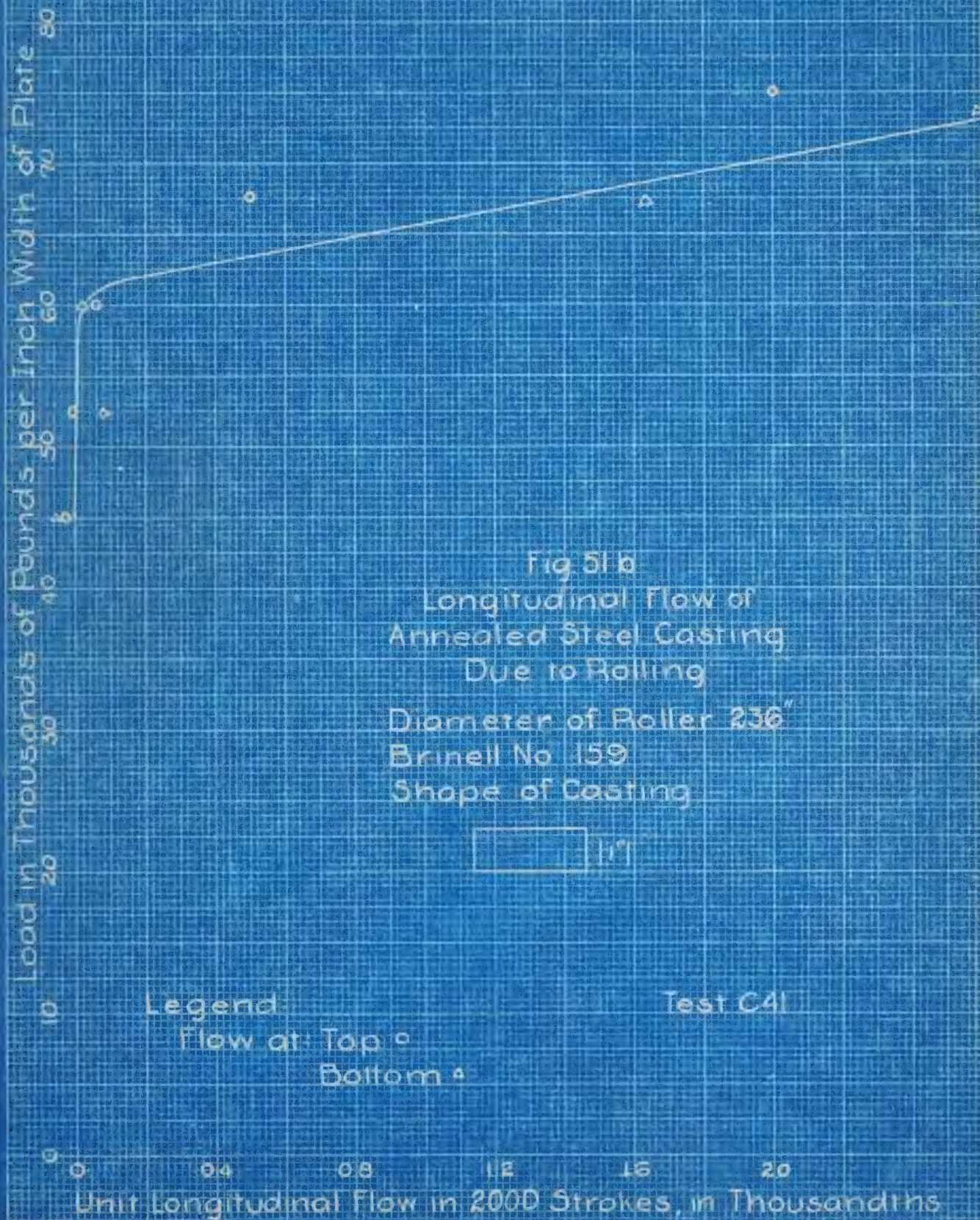


No. 1
Diameter of Roller
Kiln Roller Steel Coasting
Diameter of Roller
Diameter of Roller 206
Bore No. 59
Shape of Coasting

Legend
Flow on Top
Bottom

Test C4

Water Flow in 2000 Square Feet



Load in Thousands of Pounds per Inch Width of Floor



Fig. 36a
Lateral Flow of
Pneumatically Applied
Due to Rolling
Diameter of Roller 2 1/2"
Brinell No. 150
Surface of Rollers

Legend

Flow at Top

Bottom A

Test C42

Unit: 1000 lbs/in. 2000 Strips of 1/2 in. x 1/2 in. x 1/2 in.



Fig. 528
Longitudinal Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller 236
Brinell No. 158
Shape of Casting

Legend:
 Flow at Top: ○
 Bottom: △

Test 042

Unit Longitudinal Flow in 2000 Strokes, in Thousands of in.

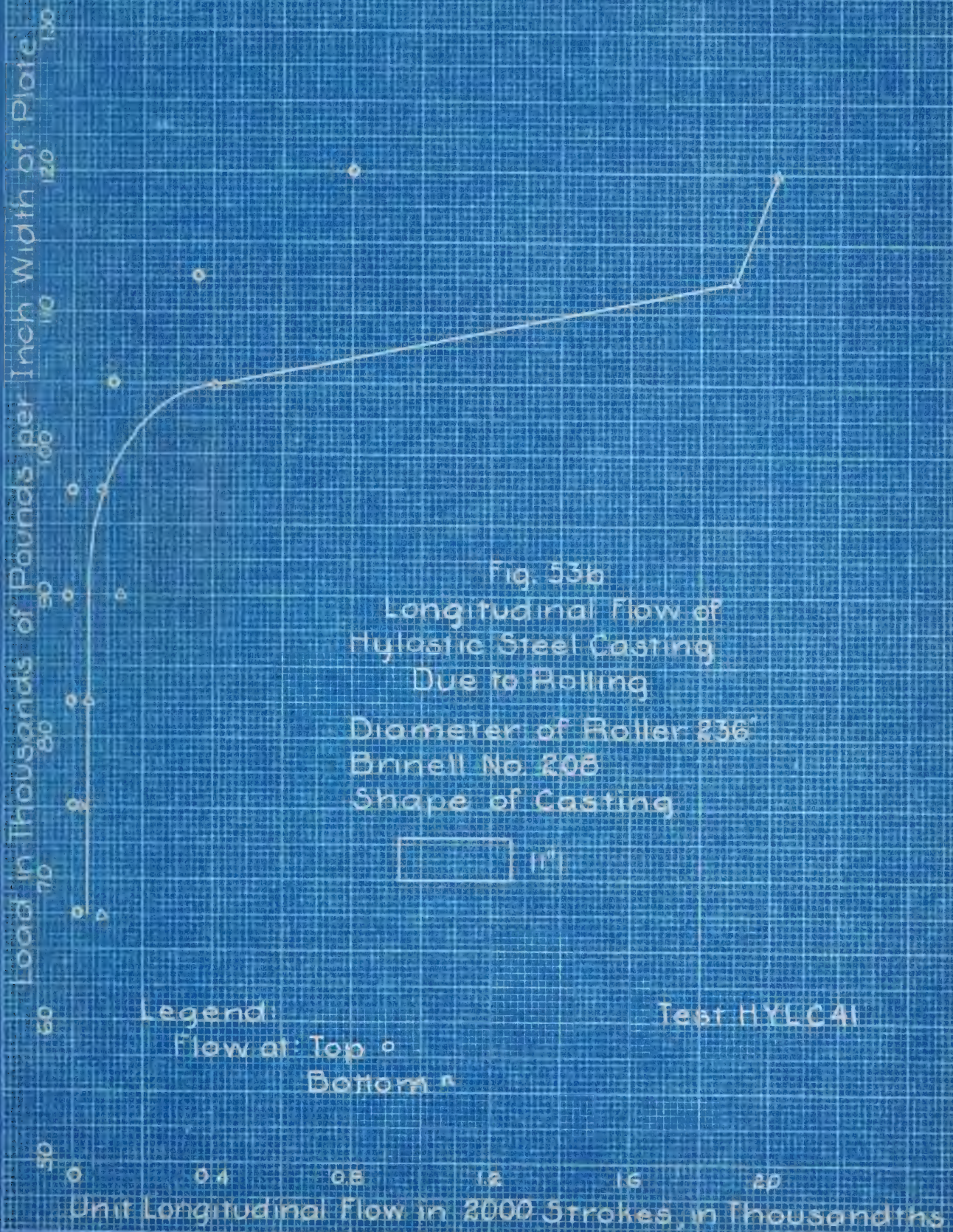
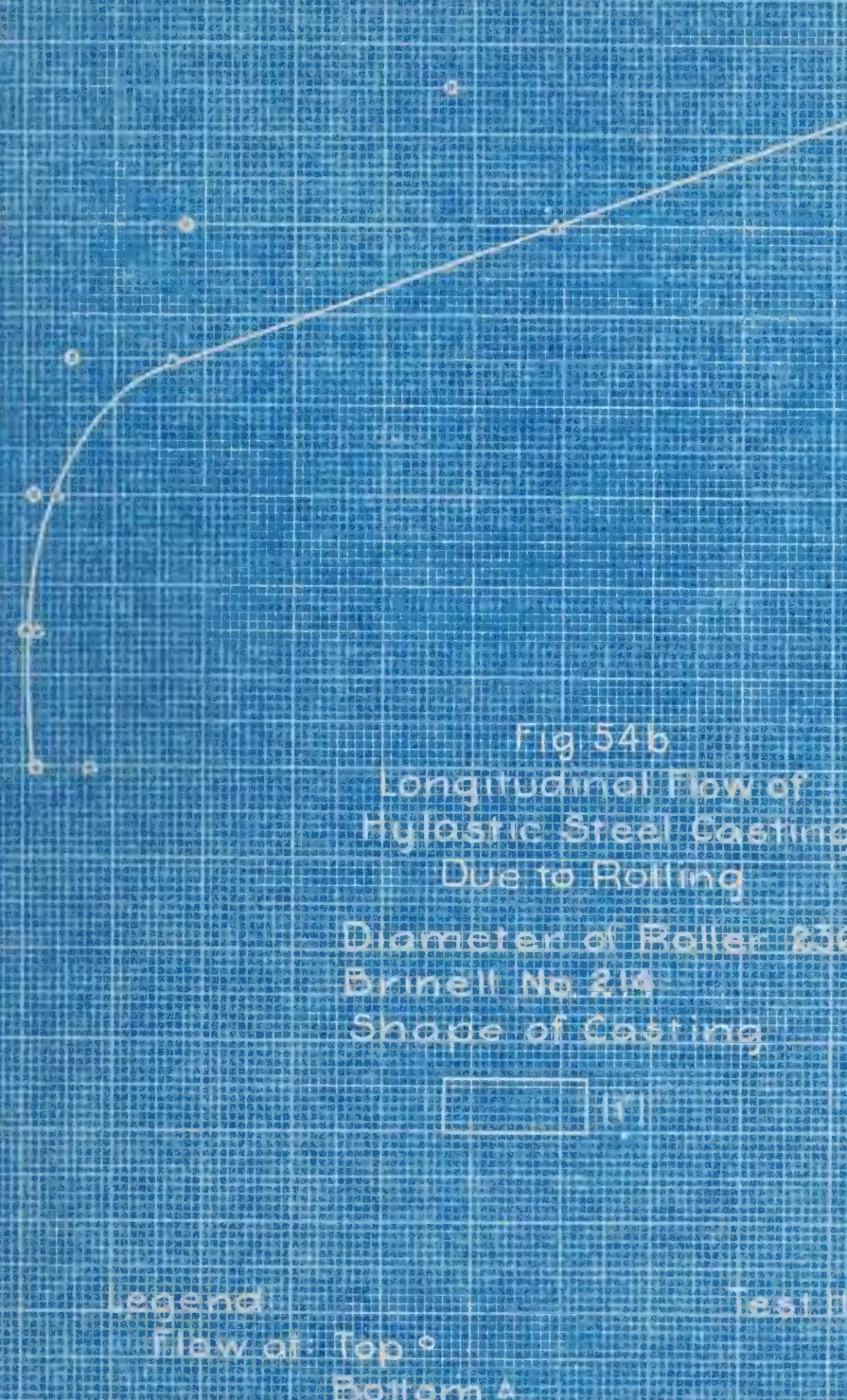


Fig. 546 shows the flow of metal in the casting of a steel casting. The flow of metal is shown by the arrows. The flow of metal is from the ladle to the mold. The flow of metal is from the mold to the casting. The flow of metal is from the casting to the spruing.



C51, C52, HYL C51 and HYL C52. The shapes and dimensions of these specimens are given in Figure 43. It will be noticed that HYL C52 and C52 have the same section and that HYL C51 and C51 are still different. The load deformation curves are shown in Figures 55 to 58 inclusive.

The critical loads are as follows:

<u>Specimen</u>	<u>From Longitudinal Flow</u>	<u>From Lateral Flow</u>	<u>From Vertical Flow</u>
C51	45000	42500	31000
C52	41500	40000	39000
HYL C51	92000	89000	70000
HYL C52	73000	73000	57000

The cross-sectional area of the web is 12 square inches. The total load on C51 at the critical load from vertical deformation is 124000 pounds, while C52 carried 117000 pounds. The average unit stress in C51 was 10,300 pounds per square inch and in C52 it is 9750 pounds per square inch.

The cross-sectional area of the web of the Mylastic specimens is 12 square inches. The total load carried by HYL C51 at the critical load for vertical deformation is 210,000 pounds while HYL C52 carried only 171,000 pounds. The average unit stresses are 17,500 pounds per square inch and 14,200 pounds per square inch respectively.

Since deformation depends on the maximum stress and not the average stress, it seems that the heavier flange of HYL C51 distributed the load to the web more uniformly than the flange of

HYL C52. This is also brought out by the slightly higher average stress in C51 than in C52.

The vertical pressure on sections parallel to the surface and at various depths is shown in Figures 59 to 62. They were calculated on the assumption that the stress is distributed uniformly on a length of plate equal to the width of area in contact plus the depth from the surface.

These values of the vertical pressure indicate that the material is overstressed.

The pressure on the web calculated by this assumption is about the same in HYL C51 as in HYL C52. The total load carried by HYL C51 with a heavier flange is 39000 pounds more than carried by HYL C52.

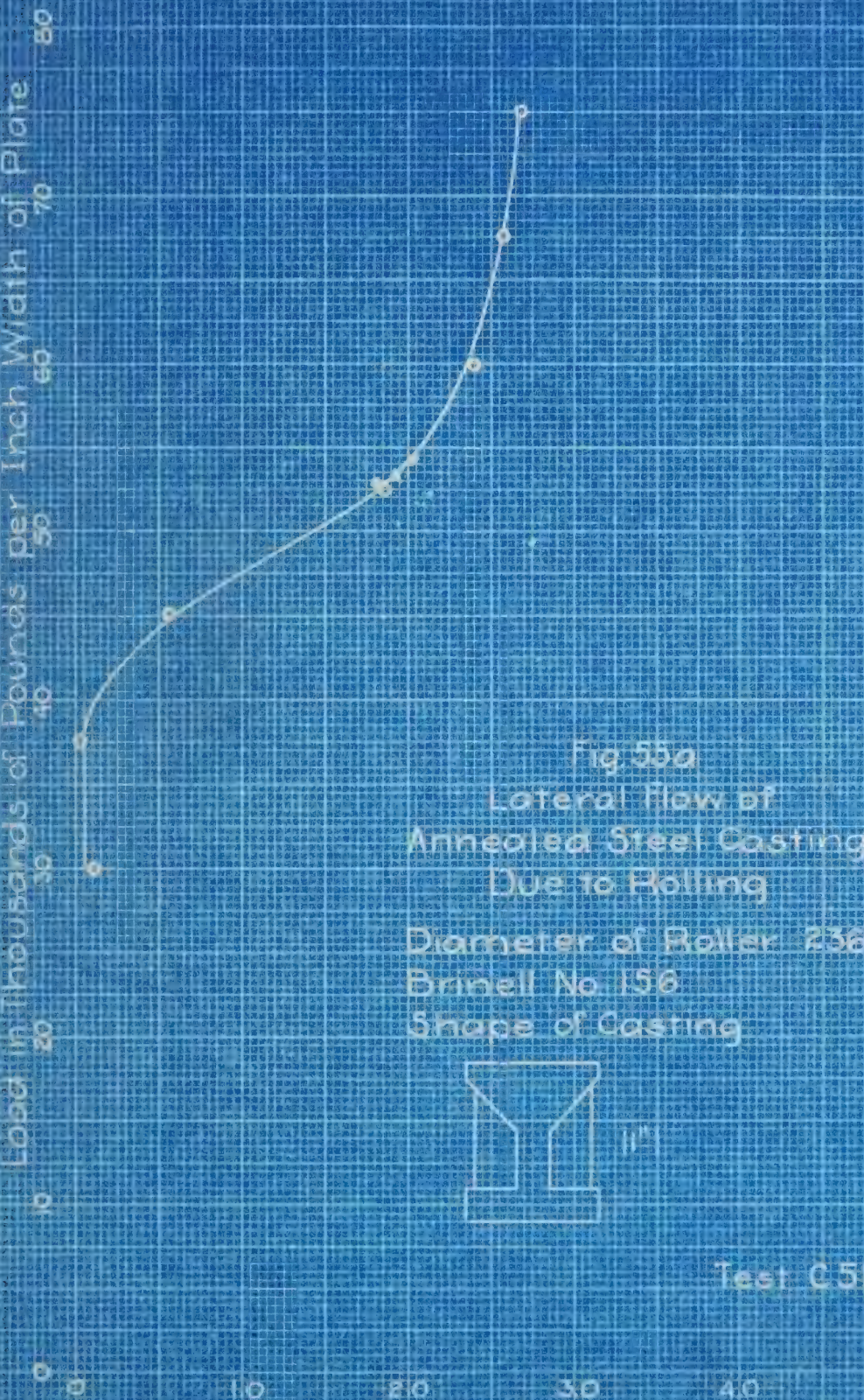
Specimen C52 is more highly stressed than C51, according to these calculations, although C51 carried the greater total load but also had a heavier flange.

The lateral and longitudinal flows in C51 and C52 show critical loads at nearly the same load per inch of width, while in HYL C51 and HYL C52 the critical loads are quite different. In the first pair of specimens, the flanges were similar while in the second pair one was $\frac{1}{2}$ inch thicker than the other, the thicker one indicating the higher critical load.

The critical load from vertical flow is lower than from either lateral flow or longitudinal flow indicating that the web is the weakest section.

The critical loads from vertical deformation for C31 and C51 are 64000 and 31000 pounds per inch width of plate respectively.

This indicates that by cutting part of the material out of the solid rectangular section making this special shaped casting the carrying capacity is greatly decreased.



Label in thousands of Pounds per Inch Width of Plate

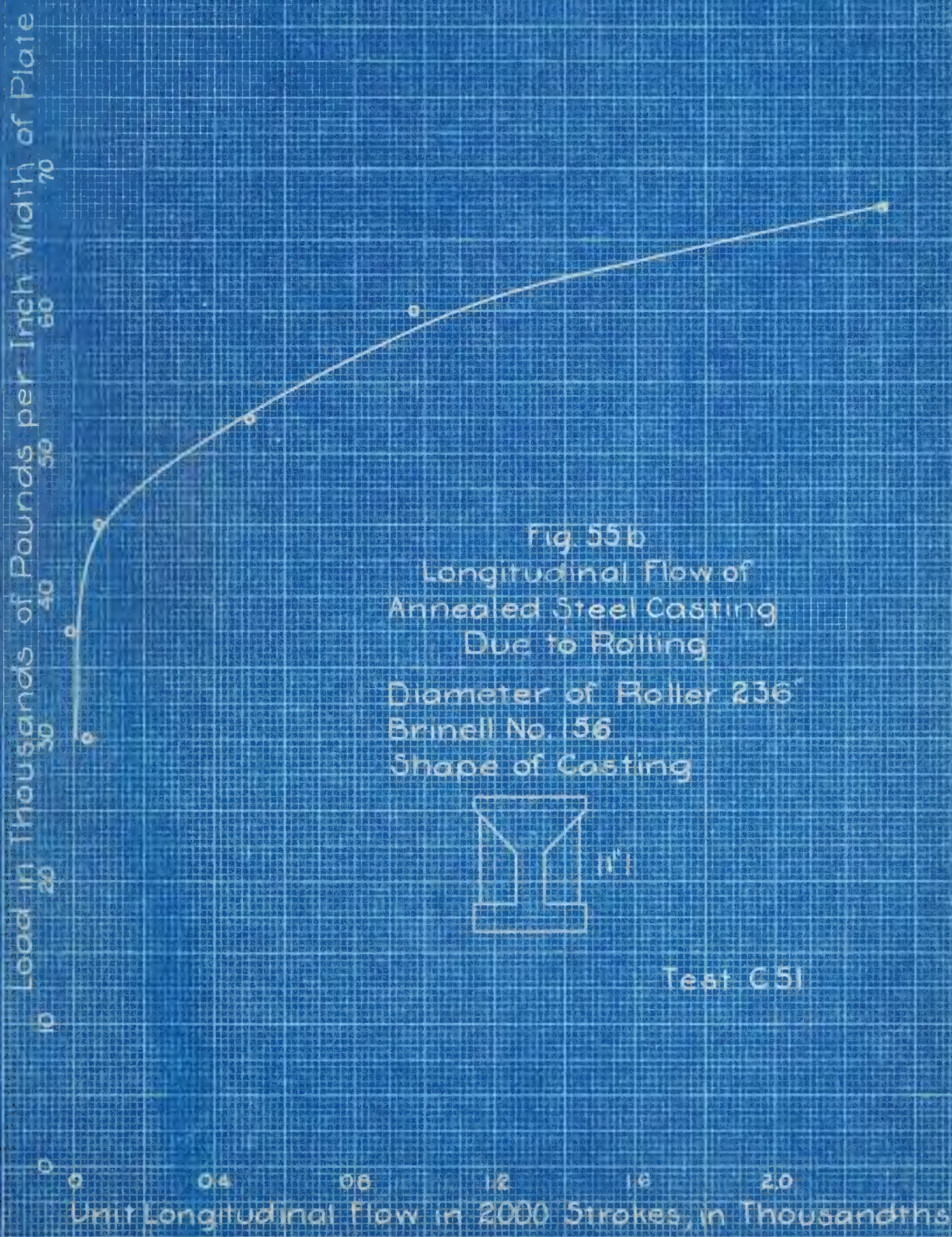
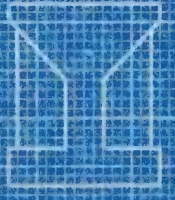


Fig. 55b
Longitudinal Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller 236
Brinell No. 156
Shape of Casting

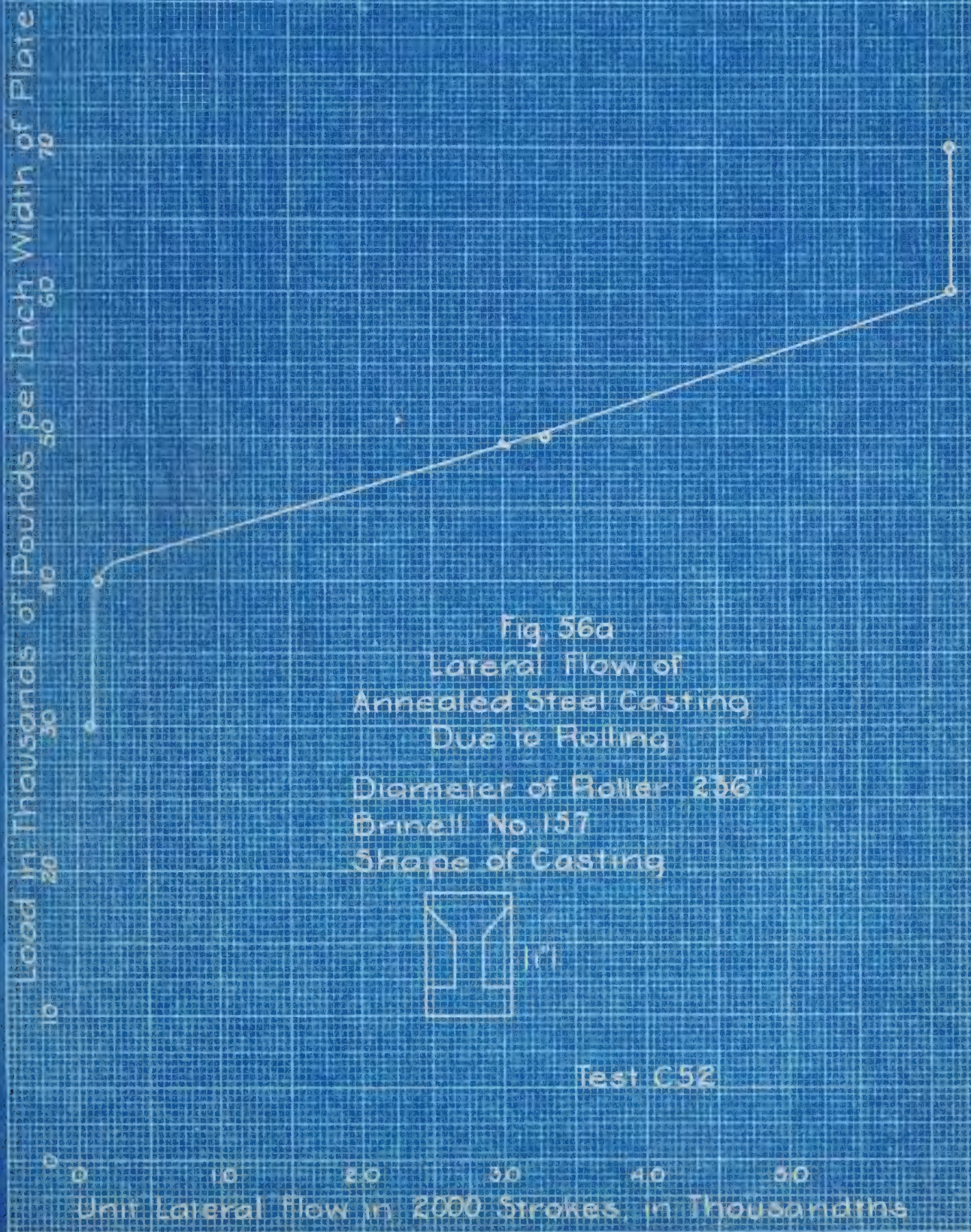


Test C-51

Unit Longitudinal Flow in 2000 Brinells in Thousandths

Figure 1. A schematic diagram of the experimental setup. The subject is seated in a chair and views the target through a video camera. The target is a small object (e.g., a ball) that is suspended in the air. The subject's hand is positioned near the target. The video camera is positioned above the target and the subject's hand. The video camera is connected to a computer, which displays the video feed on a monitor. The subject's hand is positioned near the target, and the video camera is positioned above the target and the subject's hand. The video camera is connected to a computer, which displays the video feed on a monitor.

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 一种莫名的恐惧。我害怕那
 些穿着制服的人，害怕他们
 的吼声，害怕他们的鞭子。

[illegible][illegible][illegible][illegible][illegible][illegible]

明倫彙編 家範典 卷一百一十五

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 2. 经营者应当遵守国家和本市有关价格管理的法律法规，不得有下列行为：
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 （三）囤积居奇，牟取暴利；
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 （七）违反政府指导价、政府定价规定；
 （八）其他违反价格法律法规的行为。
 3. 经营者违反本办法规定的，将依法予以处罚。

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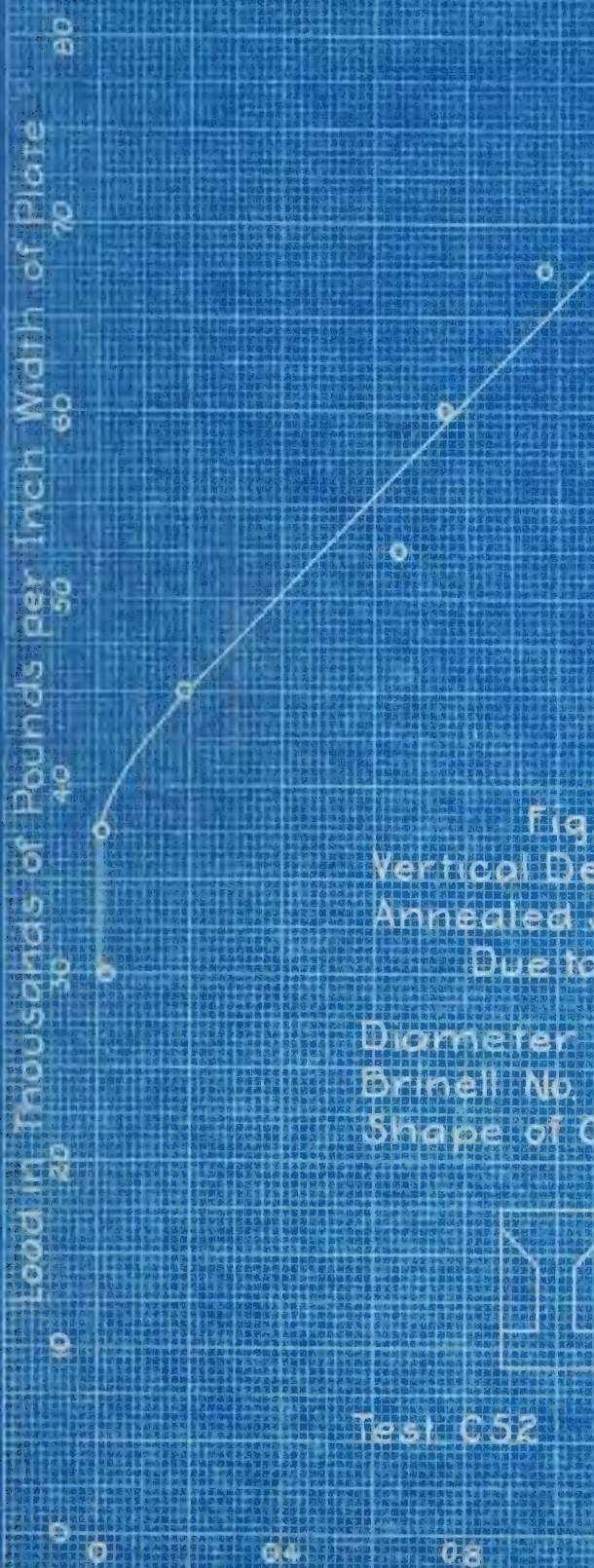
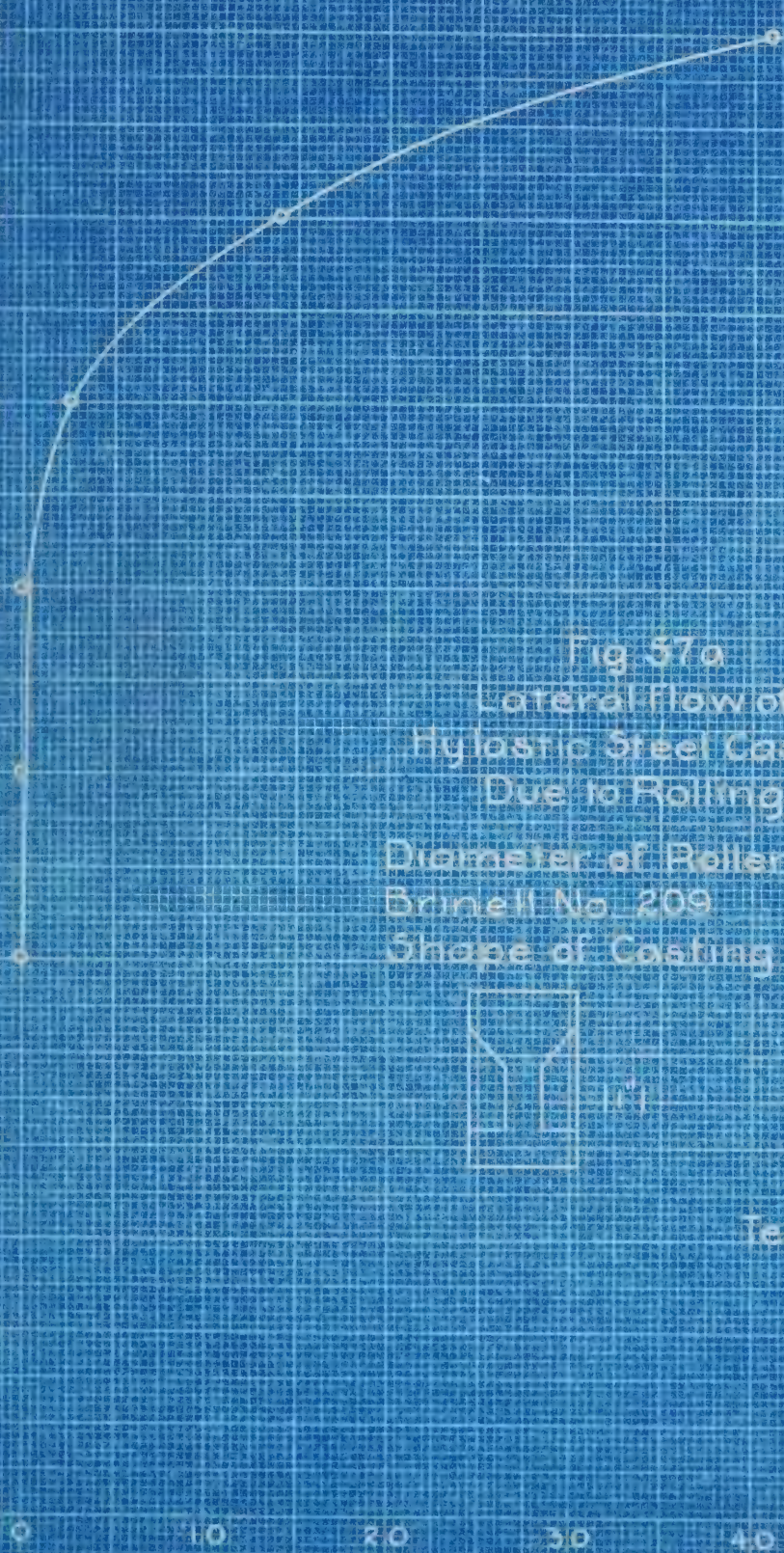


Fig. 56c
Vertical Deformation in
Annealed Steel Casing
Due to Rolling
Diameter of Roller 2 3/8
Brinell No. 150
Shape of Casing

1/16 in. 0.52

1/16 in. 0.52 0.5 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60 61 62 63 64 65 66 67 68 69 70 71 72 73 74 75 76 77 78 79 80 81 82 83 84 85 86 87 88 89 90 91 92 93 94 95 96 97 98 99 100

Load in Pounds per Inch Width of Plate



19 370
Control Flow of
Hydrostatic Steel Castings
Due to Rolling
Diameter of Roller 2-16
Brinell No. 200
Single or Castings

Roller 1/2 Y Cast

Initial Flow in 2000 Grains in Thousands

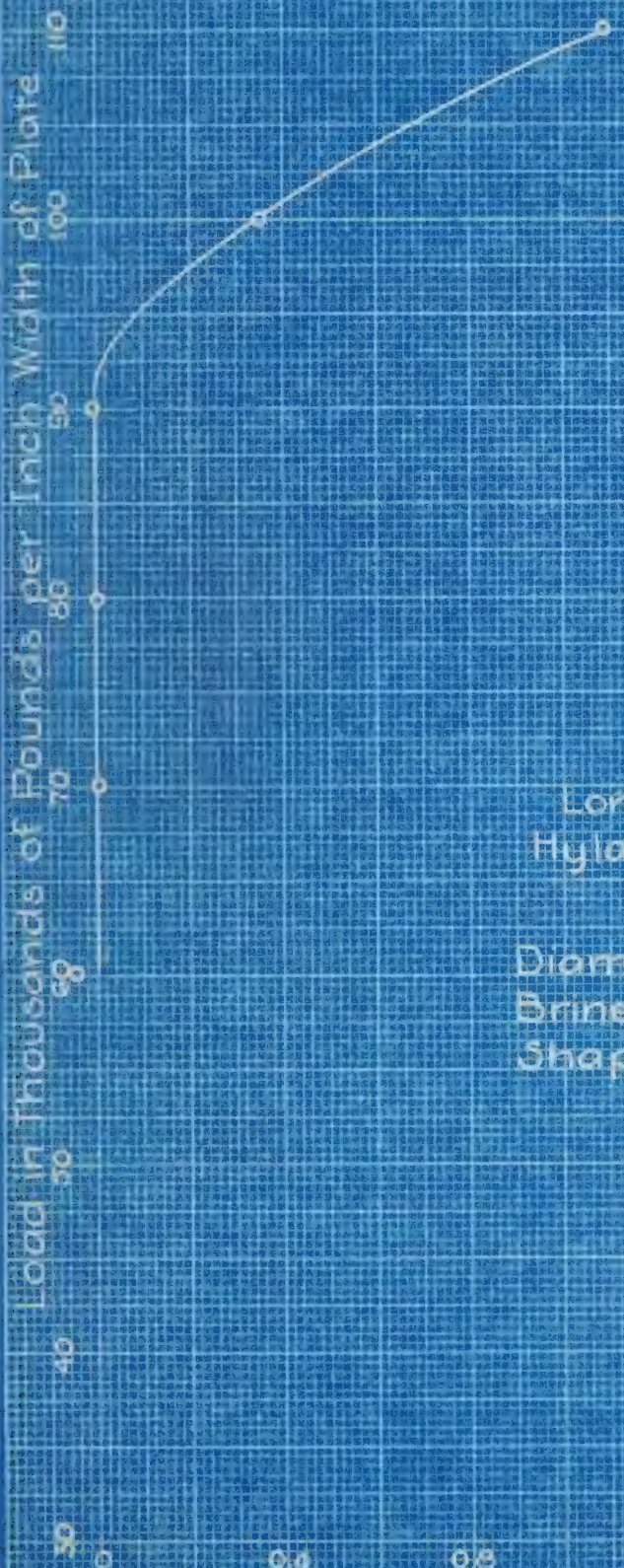
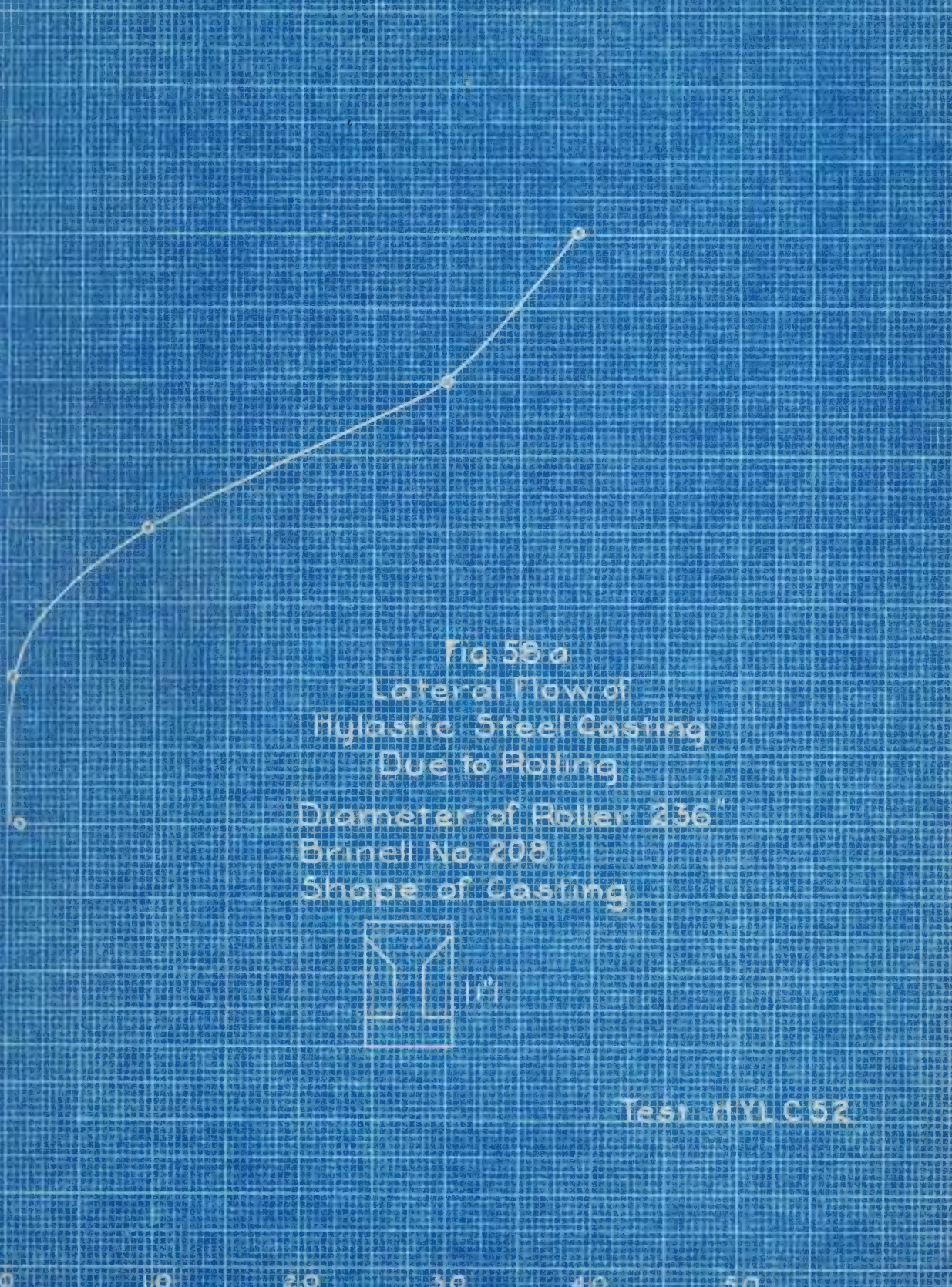


Fig. 37/b
 Longitudinal Flow of
 Hydraulic Steel Casting
 Due to Rolling
 Diameter of Rolling 236
 Brinell No. 209
 Shape of Casting



Test in Y and C

Load in Thousands of Pounds per Inch Width of Plate



No. 5610
 Lateral Flow of
 Elastic Steel Casting
 Due to Rolling
 Diameter of Roller 2.96
 Ball No. 205
 Shape of Casting
 N 7

ASTM A 105

Universal Lateral Flow in 2000 Strokes in Thousandths of an Inch

Losses in thousands of pounds per thousand tons of plate

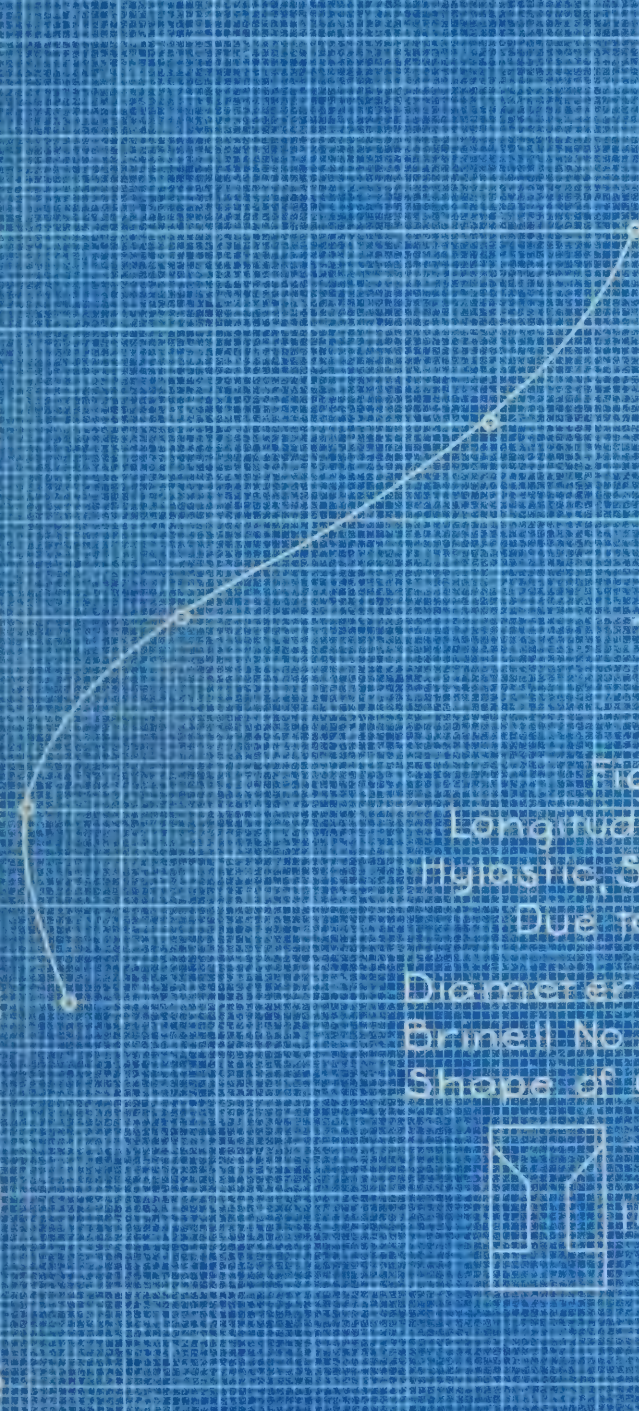


Fig. 38.16
Longitudinal Flow of
Hydrostatic Steel Casting
Due to Rolling
Diameter of Rollers 236"
Brine II No. 202
Shape of Casting



Test HYL 62

Unit Rolling Time in 2000 (minutes)

FIG. 59TESTS C 51

MATERIAL - CARBON STEEL CASTING

YIELD POINT - 43,500 LBS. PER SQ. IN

CRITICAL LOAD

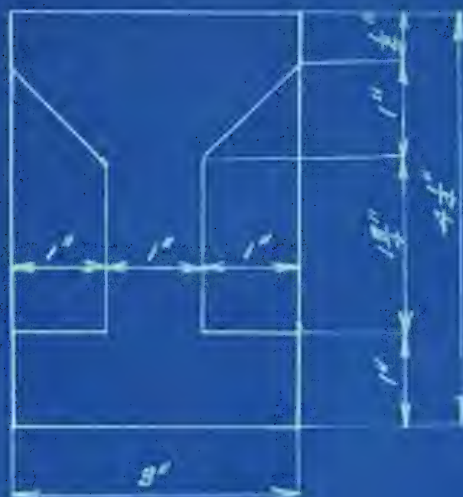
LATERAL FLOW - 43,000 LBS. PER IN. WIDTH OF PLATE

LONGITUDINAL FLOW - 42,500

VERTICAL FLOW - 31,000

UNIT VERTICAL PRESSURE

DEPTH	PRESSURE
0	28,600
0.5"	19,600
1.0"	19,800
1.5"	24,000
2.0"	40,200
2.5"	34,600

FIG. 60TESTS C52

MATERIAL - CARBON STEEL CASTING

YIELD POINT - 43,500

CRITICAL LOAD

LATERAL FLOW - 44,000 LBS PER IN. WIDTH OF PLATE

LONGITUDINAL FLOW - 40,000

VERTICAL FLOW - 39,000

UNIT VERTICAL PRESSURE

DEPTH	PRESSURE
0	32,000
05"	22,600
10"	26,400
15"	43,000
20"	36,400
25"	

FIG. 61

TESTS HYL C51

MATERIAL - HYLASTIC STEEL CASTING

YIELD POINT - 57,700

CRITICAL LOAD

LATERAL FLOW - 70,000 LBS. PER IN. WIDTH OF PLATE

LONGITUDINAL FLOW - 95,000

VERTICAL FLOW - 70,000

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UNIT VERTICAL PRESSURE

DEPTH	PRESSURE
0	43,100
0.5'	43,400
1.0'	43,700
1.5'	43,600
2.0'	43,400
2.5'	43,000

FIG. 62
TESTS HYL C52



MATERIAL - HYLASTIC STEEL CASTING

YIELD POINT - 57,700 LBS. PER SQ. IN.

CRITICAL LOAD

LATERAL FLOW - 75,000 LBS. PER IN. WIDTH OF PLATE

LONGITUDINAL FLOW - 75,000

VERTICAL FLOW - 57,000

UNIT VERTICAL PRESSURE

DEPTH	PRESSURE
0	38,800
5"	28,900
10"	34,600
15"	57,500
20"	48,200
25"	

C61, C62, NYL C61 and NYL C62. The shape and dimensions were the same in all these specimens and are shown in Figure 48. The load-deformation curves are given in Figures 65 to 66. The critical loads are as follows:

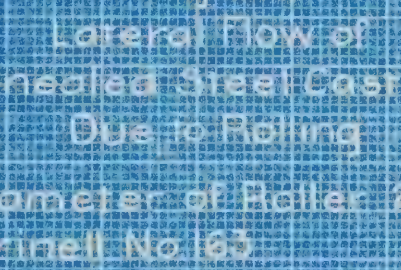
<u>Specimen</u>	<u>Lateral Flow</u>	<u>Longitudinal Flow</u>	<u>Vertical Flow</u>
C61	37500	38500	37500
C62	37500	37500	37500
NYL C61	67500	63500	61000
NYL C62	67500	66000	61000

Figures 67 and 68 show the stress at different depths in the plates on the foregoing assumption of stress distribution.

The yield point of the material in C61 and C62 is 43,500 pounds per square inch and that of NYL C61 and NYL C62 is 57,660 pounds per square inch. The calculated stresses indicate that the material is over stressed.

The effect of the stiffeners seems to be detrimental. The total load carried by C61 at critical load from vertical deformation was 150,000 pounds while C51 carried only 124,000 pounds.

The critical load from vertical flow of C61 and C62 is 37,500 pounds per inch width of plate which is about .6 of the critical load from vertical flow of C31 which has a solid rectangular section.



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Logarithm of Pounds per Inch Width of Plate

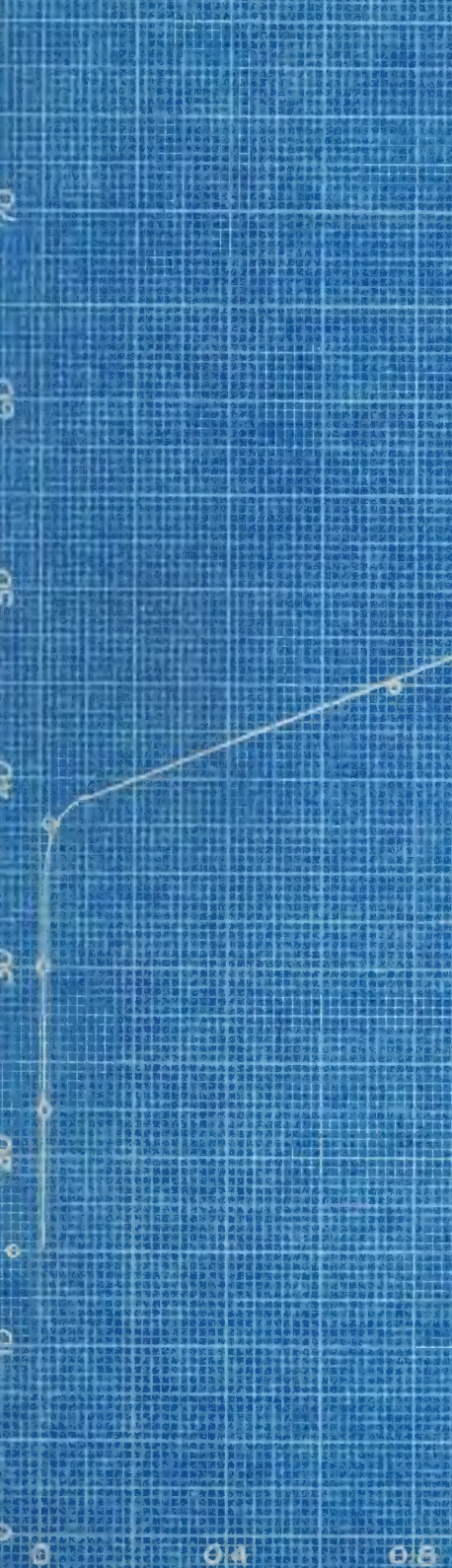


Fig. 63b
Longitudinal Flow of
Annealed Steel Casting
Due to Rolling
Diameter of Roller 236
Brinell No. 163
Shape of Casting



Test C-61

Longitudinal flow in 2000 strokes, in thousandths

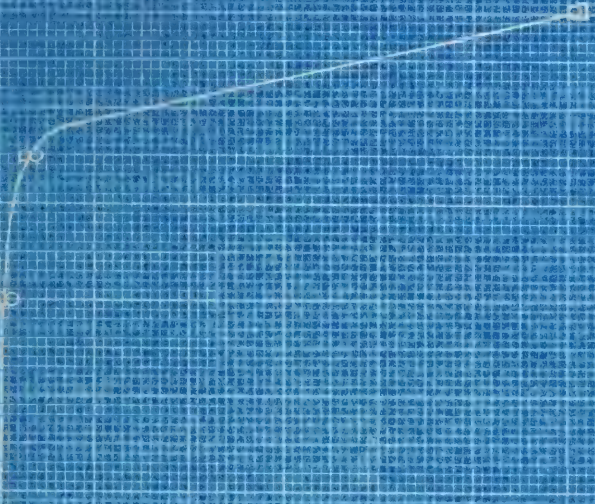
Fig. 63c Vertical Deformation in Annealed Steel Casting Due to Rolling

Diameter of Roller, in.
Brinell No. 163-151
Shape of Casting



Legend
Test Cell
Test Block

Depth in thousands of pounds per inch Width of plate



Local in Thousands of Pounds per Inch Width of Plate

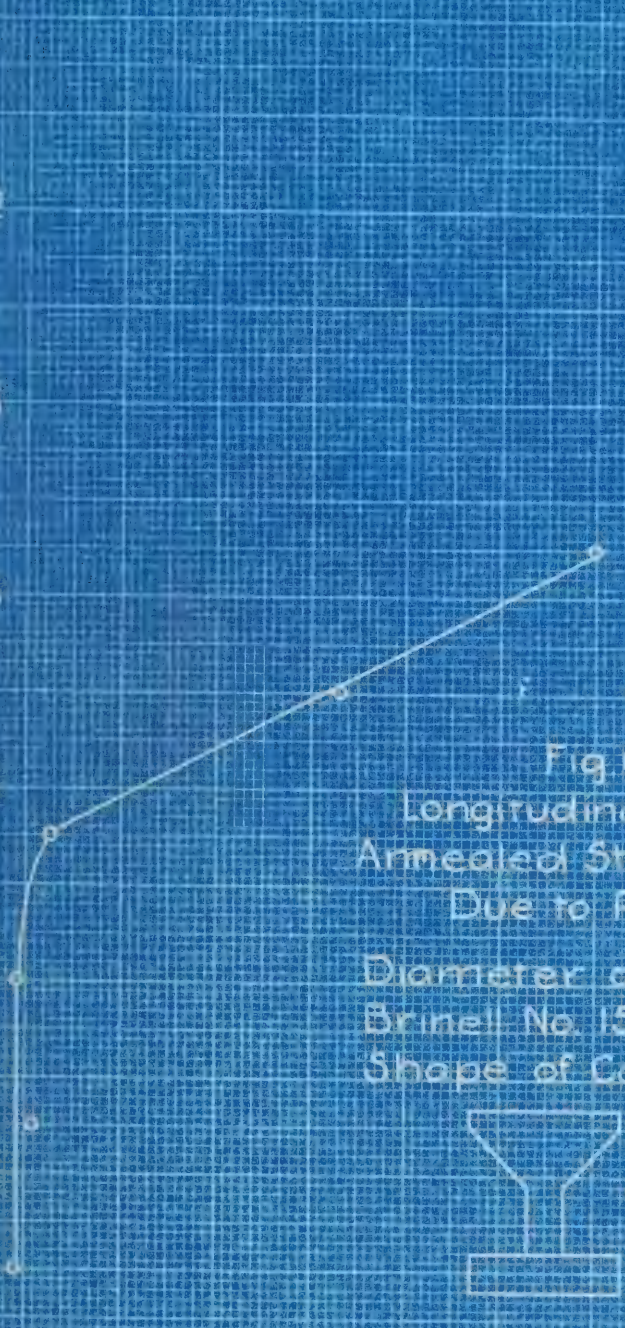
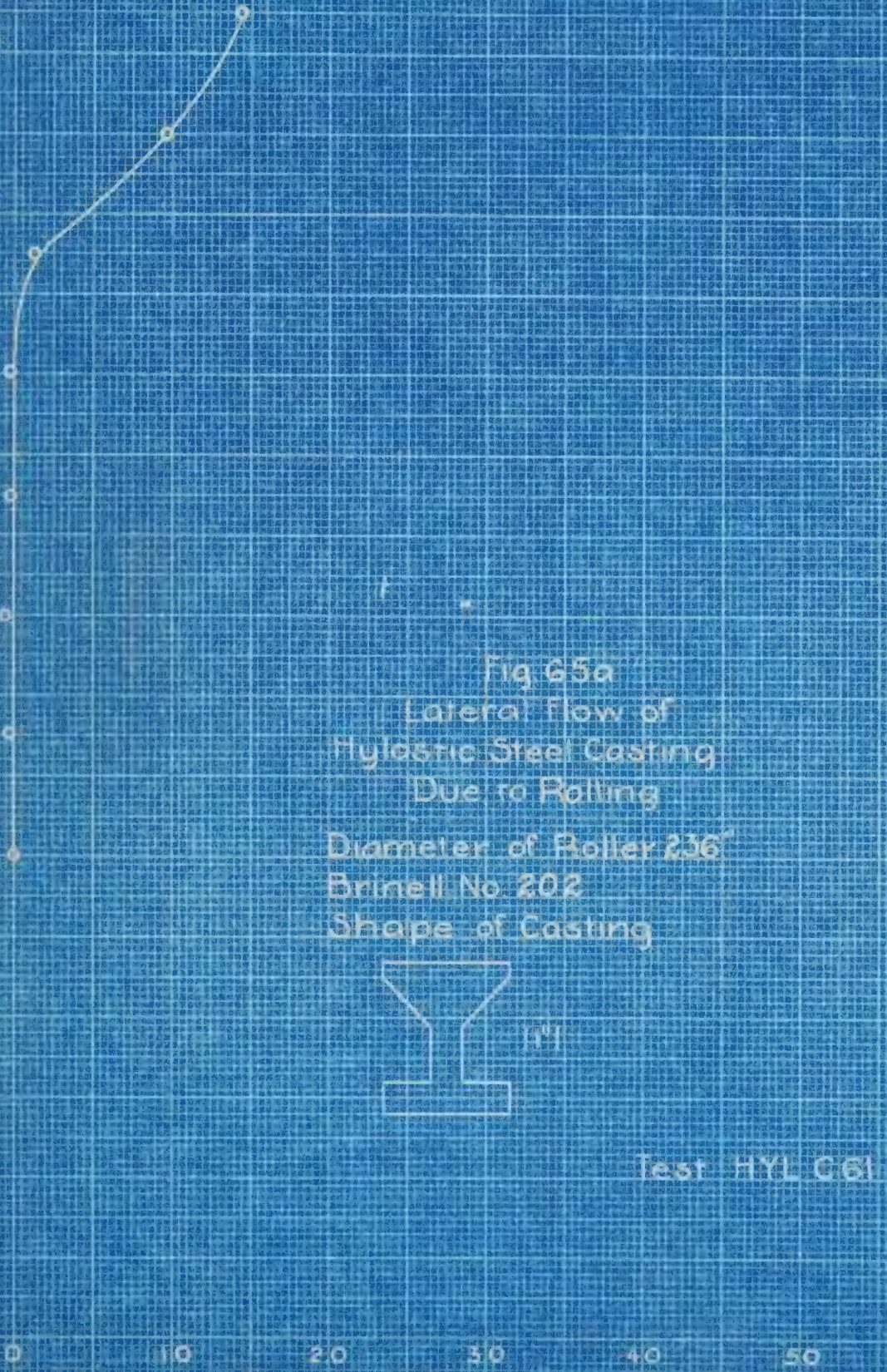


Fig. 64b
Longitudinal Flow of
Armored Steel Casting
Due to Rolling
Diameter of Roller 2-6
Drum No. 57
Slope of Casting

11

Res. 062

Flow in 2000 Smokes in Thousands



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Flow in 2000 Smokes in Thousands

Lead in Thousands of Pounds per Inch Width of Plate

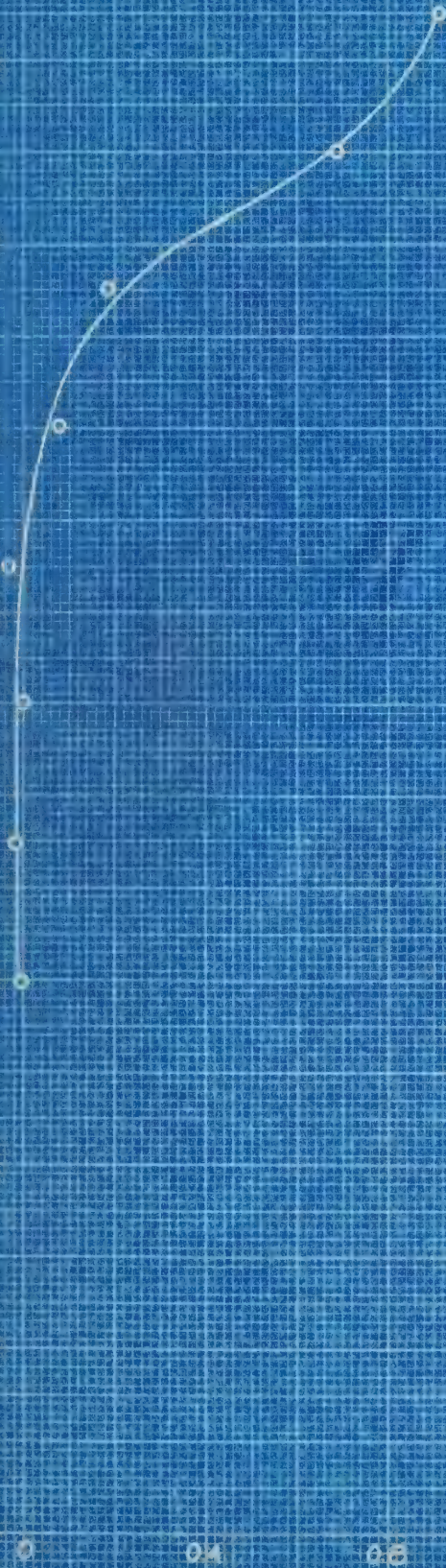
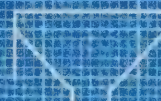
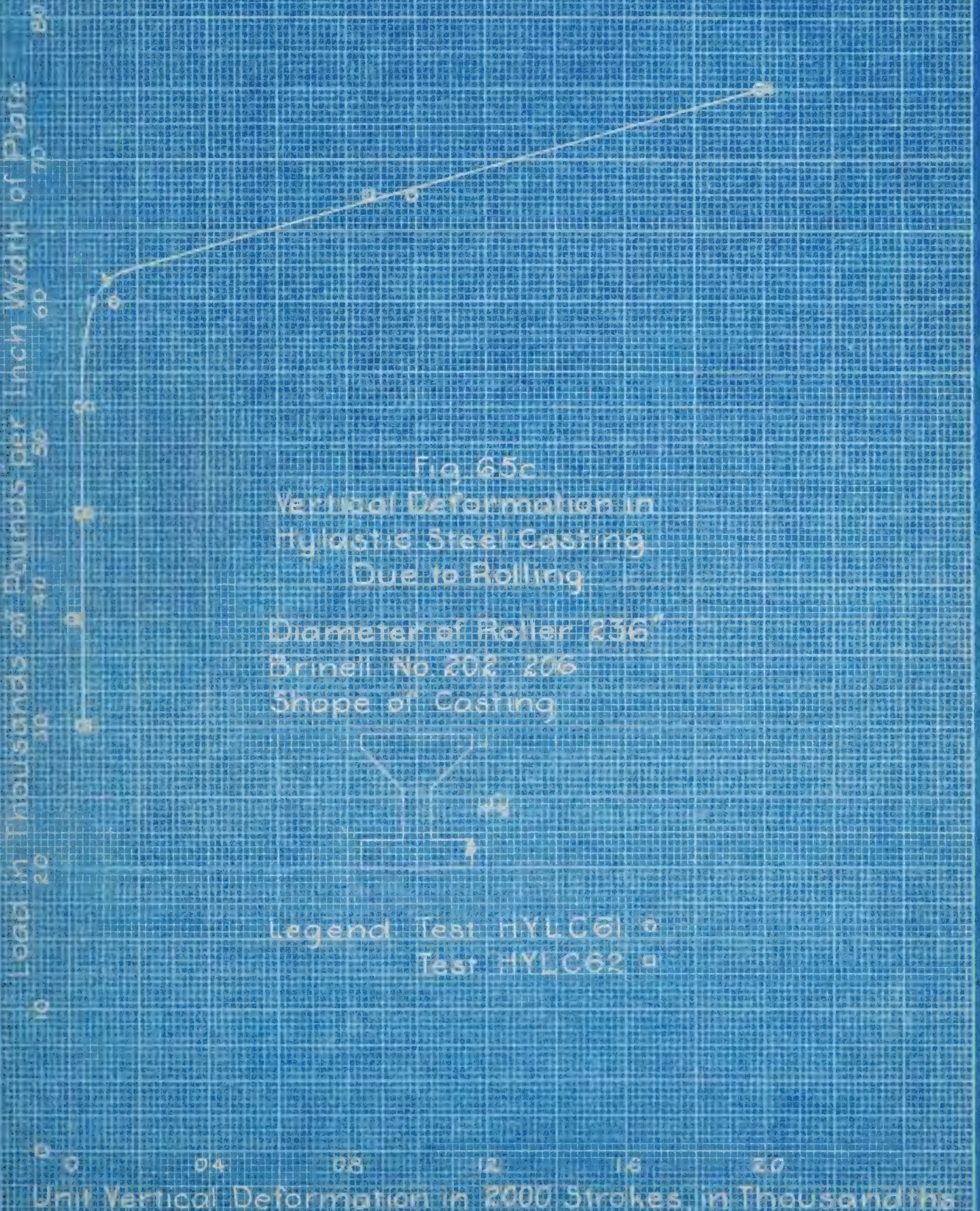


Fig. 65b
Longitudinal Flow of
Hydrostatic Steel Casting
Due to Rolling
Diameter of Roller 23 1/2"
Brinell No 202
Shape of Casting



Test No. 66

Longitudinal Flow in 2000 Strokes in Thousands of Inches



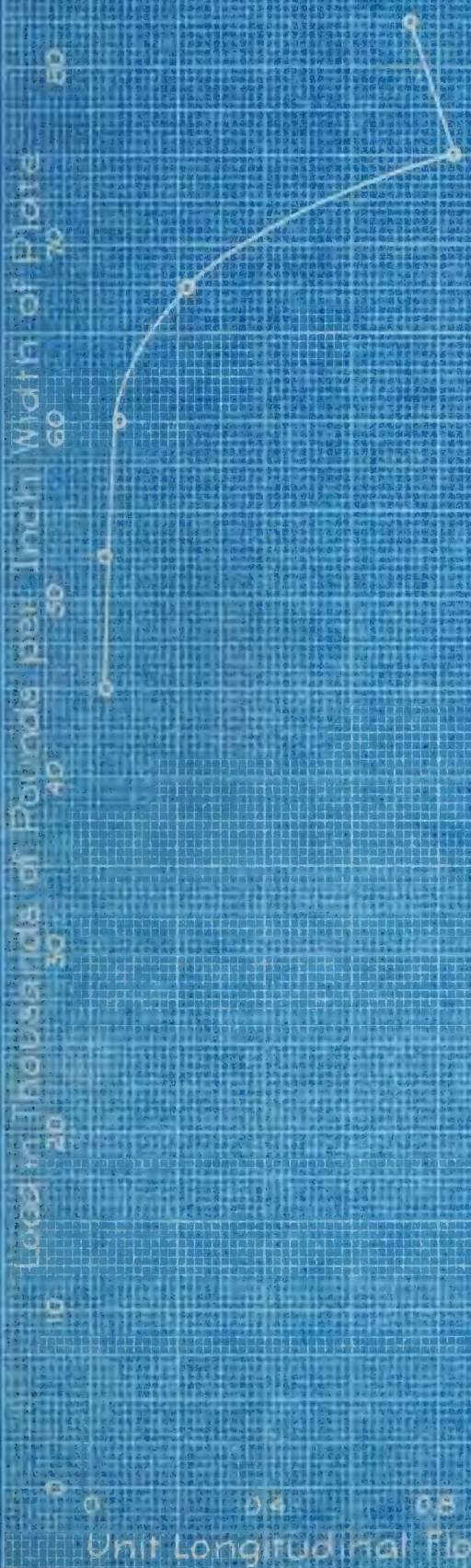


Fig. 66b
Longitudinal Flow of
Mylastic Steel Casting
Due to Rolling
Diameter of Roller 2.56
Barrel No. 200
Shape of Casting



Roller No. 200

Unit Longitudinal Flow in 2000 Strokes in Thousandths of an Inch

FIG. 67
TESTS C61 AND C62



MATERIAL - CARBON STEEL CASTING

YIELD POINT - 43,500 LBS. PER SQ. IN.

CRITICAL LOAD

LATERAL FLOW - 37,500 LBS. PER IN. WIDTH OF PLATE

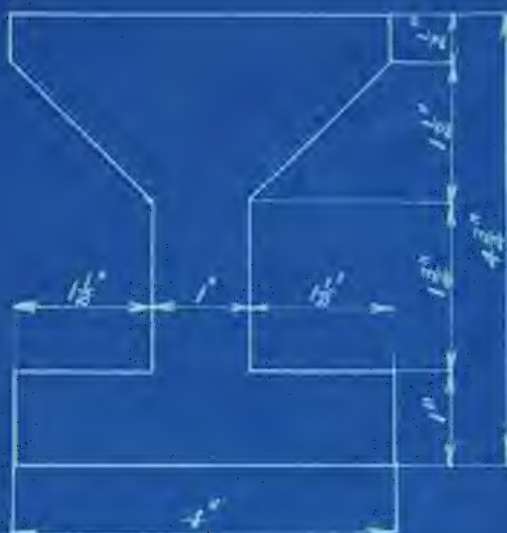
LONGITUDINAL FLOW - " "

VERTICAL FLOW - " "

UNIT VERTICAL PRESSURE

DEPTH	PRESSURE
0	31,300
05"	22,000
10"	22,800
15"	27,800
20"	47,000
25"	40,500

FIG. 68
TESTS HYL 661 AND HYL 662



MATERIAL - HYLASTIC STEEL CASTING

YIELD POINT - 57,100 LBS. PER SQ. IN.

CRITICAL LOAD

LATERAL FLOW - 66,700 LBS. PER IN. WIDTH OF PLATE

LONGITUDINAL FLOW - 67,500

VERTICAL FLOW - 61,000

UNIT VERTICAL PRESSURE

DEPTH	PRESSURE
0	37,600
2.5"	29,300
10"	31,500
15"	39,600
20"	47,100
25"	58,800

APPENDIX

PHYSICAL PROPERTIES OF MATERIAL FOR SMALL
ROLLER TESTS.

PHYSICAL PROPERTIES OF MATERIAL FOR SMALL
ROLLER TESTS.

The physical properties of the small rollers are given in Table 7. They were determined by standard tension tests. Figure 69 shows the location of each specimen and the portion removed from the original block in making the rollers.

Table 1 is superceeded by Table 8. The values in Table 1 are the results of a single test while the values in Table 8 are the average of two duplicate tests.

TABLE 7 PHYSICAL PROPERTIES OF Rollers
Bearing Value of Small Rollers.

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Specimen		Ultimate Strength	Yield Point	Reduction of Area	Elongation in 2 inches	Brinell Number	
Roller	Location					Before	After
H1	S1	64 030	30 990	40.7	26.2	116	148
	S2	66 050	33 340	43.0	26.8		
	S4	66 450	34 630	42.0	26.5		
	S5	64 820	32 740	38.5	27.0		
	S6	66 620	32 110	44.3	25.6		
H2	S1	63 420	35 020	25.0	23.6	117	144
	S2	59 450	36 570	14.9	8.04		
	S4	55 160	37 750	19.0	8.8		
	S5	64 160	33 780	45.1	26.3		
H3	S1	57 270	32 110	20.08	9.5	126	148
	S2	60 550	34 390	19.78	16.00		
	S3	49 360	29 670	20.6	8.1		
	S4	60 300	34 340	10.6	9.5		
	S5	64 630	31 830	21.6	19.2		
	S6	65 680	30 600	36.6	26.2		
H3A	S1	61 170	31 480	22.9	14.6	133	151
	S2	62 930	31 810	12.77	7.2		
	S4	64 260	34 210	16.83	14.16		
	S5	55 760	32 350	17.24	8.25		
H5	S2	35 466	35 466	—	—	128	133
	S5	61 560	33 760	9.98	7.5		
	S3	43 480	30 990	8.41	3.75		
	S4	65 530	34 320	27.65	22.25		
H5A	S1	46 610	30 260	14.06	6.37	126	158
	S2	42 700	31 980	17.54	6.14		
	S4	62 440	32 570	26.21	16.75		
	S5	63 060	30 820	23.67	20.5		
	S6	62 980	31 470	27.04	24.0		
H7	S2	63 490	32 030	27.90	24.3	128	169
	S3	40 220	33 100	—	—		
H9	S1	23 650	23 650	—	—		
	S4	29 330	29 330	—	—		
	S5	63 400	33 860	38.54	22.5		
	S6	62 760	30 710	25.10	20.2		



Fig. 69
Diagram Showing Location of Specimens
in Original Block

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